2005

A national study of scientific talent development in Singapore

Chwee Geok Quek
William & Mary - School of Education

A NATIONAL STUDY OF SCIENTIFIC TALENT DEVELOPMENT IN SINGAPORE

A Dissertation

Presented to

The Faculty of the School of Education

The College of William and Mary

In Partial Fulfillment

Of the Requirements for the Degree

Doctor of Philosophy

---

by

Chwee Geok Quek

April 2005

A national study of scientific talent development in Singapore

by

Chwee G Quek

Approved May, 2005

Joyce L. VanTassel-Baska, Ed.D.
Chairperson, Doctoral Committee

Michael, F. DiPaola, Ed. D.

James H. Stronge, Ph.D.

Table of Contents

ACKNOWLEDGEMENTS

I would like to place on record my appreciation to the survey respondents for their time and insightful comments. I would also like to thank the members of my dissertation committee for their invaluable advice, comments and suggestions. To Dr Michael DiPaola and Dr James Stronge, I am grateful for their support, encouragement and confidence in me.

To the chair of my committee and my advisor, Dr Joyce VanTassel-Baska, I am immensely thankful for her wise counsel and expert and caring guidance. She is the most effective teacher I have ever encountered. She knows when and how to push her students to where our hearts and minds can go. She gave me a lot of freedom to pursue research areas that interest me, and always encouraged me to push the boundaries of my work. I have enjoyed all the academic challenges and diversions during my three years at the college, and feel honored to have had the opportunity to learn from one of the finest scholars in the field. I also deeply appreciate her interest in my professional life and personal well-being. Whenever I am discouraged, she is always there to lend moral support and offer advice and praise. Her confidence in me has remained steady even as my own wavers. Her interest in other cultures, strong work ethic, prolific accomplishments and commitment to scholastic integrity will continue to inspire me. I feel extremely privileged to have been under the tutelage of Dr VanTassel-Baska, scholar, mentor, and teacher par excellence for whom I have the deepest respect and affection. The impact she has made on me is greater than she could ever imagine.

List of Tables

List of Figures

A NATIONAL STUDY OF SCIENTIFIC TALENT DEVELOPMENT IN SINGAPORE

ABSTRACT

Three cohorts comprising a total of 155 gifted science students who had participated in a research mentorship program, the Science Research Program (SRP) in Singapore, were surveyed in this cross-sectional study. Adapting Gagne's (2003, 2004) *Differentiated Model of Giftedness and Talent (DMGT)* as a conceptual framework, this study examined the intrapersonal and environmental catalysts that students perceived to have contributed to their talent development in the sciences. It also sought to evaluate the impact of the SRP on the students, and the extent to which it reinforced their passion for the sciences, and decision to pursue careers in science and /or research.

Respondents attributed the biggest role to the 'self' in their talent development journey. They perceived that various intrapersonal qualities they had – sense of curiosity, passion for the subject as well as persistence – were most important in nurturing and sustaining their interest and engagement in science. The external catalysts of teachers and the school appeared to have played a bigger role than parents and the home in respondents' perceptions of the influences on their scientific talent development process. Qualitative descriptions of inspiring and memorable teachers were consistent with qualities of effective teachers in the literature.

Findings also showed that students felt the SRP had been very effective in enhancing their scientific knowledge and skills, but that it was less impactful in shaping their future course and career decisions. Indeed, except for a handful who reported that the SRP actually helped them discover that science was not really their passion, the majority plan to pursue careers in science, both in research and in applied fields, aspirations they have had since childhood. There appeared to be little attrition of this group from the science pipeline although there are some indications that more might need to be done to attract more gifted females to the field and to help them remain in the field.

Based on the findings, suggestions for future research directions are offered. Recommendations for practice and policy are also discussed.

CHWEE GEOK QUEK

PROGRAM IN EDUCATIONAL PLANNING, POLICY AND LEADERSHIP

THE COLLEGE OF WILLIAM AND MARY IN VIRGINIA

A NATIONAL STUDY OF SCIENTIFIC TALENT DEVELOPMENT IN SINGAPORE

Chapter 1

Statement of the problem

Introduction

The mission of the education service in Singapore is to "mould the future of the nation by moulding the people who will determine the future of the nation. The service will provide our children with a balanced and well-rounded education, develop them to their full potential, and nurture them into good citizens, conscious of their responsibilities to family, society and country" (Ministry of Education [MOE], 2004).

In a land-scarce and resource-scarce country which covers an area of 685 square kilometers (about the size of Rhode Island) and has a population of about four million, its very survival depends solely on its precious human resources. Every child will be taught at a pace commensurate with his ability to enable him to develop his individual aptitudes. Every child will be equipped with the skills and knowledge, as well as the right values and attitudes to be assured of a livelihood. Education will nurture a nation of caring and thinking citizens capable of and committed to contributing to Singapore's continued growth and prosperity.

Economics and science

In its 39 years of independence, Singapore has been relatively successful in finding its niche in the world economy, nimbly responding to external changes beyond its control. Today, against the backdrop of increasing economic competition from China, India, and other Southeast Asian neighbors, it is trying to find its niche in the knowledge-based economy. The knowledge-based economy that now drives the world's growth is at its core about innovations in science and technology. Unable to compete with rising economies on the basis of low labor costs, Singapore has to concentrate on industries higher up on the value chain. Her ambition is to become an international biomedical hub in Asia, where the knowledge-intensive biomedical sciences industry can be built and developed to generate sustainable growth and high value jobs. The government has been very aggressive in attracting leaders in the field to work in Singapore. It has invested three billion dollars in research of all types and has succeeded in attracting more than 1000 science PhDs to relocate to Singapore, among them Nobel laureate Sydney Brenner, and Alan Colman, the geneticist who cloned Dolly. The plan is for these foreign scientists to train a new generation of Singaporean researchers. Getting to this point would require an overhaul of the education system which has always been based on rote memorization. For the future generation of Singaporean researchers to materialize, the government would also have to step up efforts to attract more gifted science students to the field.

To this end, the National Science and Technology Board, now known as Agency for Science, Technology and Research (A*STAR) was established in 1991. Its goal is "knowledge creation and exploitation of scientific discoveries for a better world... We do it by fostering world-class scientific research and nurturing world-class scientific talent for a vibrant knowledge-based Singapore. A*STAR represents today's research scientists and future generations of aspiring scientists who dare to race with the world's best towards the very limits of modern science. Together with scientists we will build up our intellectual capital and our scientific capabilities. That will boost the economic competitiveness of Singapore" (Agency for Science, Technology and Research [A*STAR], 2004). Generous scholarships are awarded to deserving students to pursue studies in science, up to the doctoral level. Those who take up these scholarships are aware of the responsibility they are undertaking to be involved in scientific endeavors to ensure the country's continued prosperity. While addressing the recipients of science scholarships awarded by A*STAR, Dr Balakrishnan (2004), Minister for Community, Youth, and Sports, and Second Minister for the Ministry of Trade and Industry, told the scholarship recipients:

> [Singapore is optimistic about its future because] we have a robust and growing talent pool...Talent is integral not only to the advance of science, but to the sustainable growth of our economy. Deep knowledge of science, and cutting edge scientific research and technological development is vital if we are to continually create value in the biomedical, chemical, electronics and infocomm sectors. (p. 4)

Educational reform

We should make what is important measurable,
and not what is measurable important

\- Eric Jensen -

Although many changes have been implemented in the educational system for the last two decades, the prevalent feeling remains the same: it is too exam-oriented and breeds compliance. To geneticist Colman, "compliance is part of the problem for the future. '[People] don't think for themselves...[t]his runs through to science" (Luman, 2004). The root problem, it seems, lies with the ubiquitous national examinations at the end of Grades 6, 10 and 12. The curriculum might have been trimmed to allow more instructional time for critical and creative thinking activities, and teachers might have been experimenting with innovative teaching strategies and designing experiential learning activities, but students still end up memorizing voluminous factual information for the national exams which have not changed very much. In the spirit of Jensen's quote, the Ministry has tried to reduce the weighting on exam grades for entry to the local universities. Universities now give credit to students who are active in the co-curricular activities, and mandatory team project work also counts towards the criteria for admission to the local universities. At the pre-tertiary level, changes have also been made to the Cambridge General Certificate-in Education (GCE) 'Advanced' Level examination. The format has been changed so that the test would be less about rote memorization, and more about the application of key concepts and skills. For instance, a new subject, similar to the International Baccalaureate's Theory of Knowledge has been made mandatory for all high school students.

Still, tinkering with the exam system will not benefit the small percentage of very bright students who are clearly university-bound. These students, like all the others, take two national exams in the span of two years – once at the end of Grade 10, and another at the end of Grade 12. To save the time spent on preparation of high stakes national exams, it was decided that the top ten percent of students enrolled in the country's top secondary schools and junior colleges need not take the end of Grade 10 GCE 'Ordinary' Level exam. Instructional time used to prepare for the exam can be better used for project work, creative activities, community service, and research work. These schools offer what is now known as the Integrated Program where transition from secondary school (Grades 7 to 10) to high school (Grades 11 and 12) would be seamless, and uninterrupted by an external national exam.

Rationale for the study

In this new educational landscape, bright students have a wider range of options. Those who prefer the 'O' Level track may continue with it. Others can proceed directly to the 'A' Level Exam. Yet others may opt for the International Baccalaureate Diploma. Indeed, the National University of Singapore (NUS) High School of Math and Science, which admitted its first cohort of 7^{th} and 9^{th} graders in 2005, will issue its own diploma, which will be recognized by local universities in their admissions policy. With a lot more instructional time at their disposal, what will students in the Integrated Program be doing that is different from the curriculum of the conventional 'O' Level track? This headline from the *Straits Times* is probably a good indicator of the things to come: *1000 students to 'cut' classes to research at Biopolis lab* (Lee, 2004). According to the report "as part of the national push to promote research in the biomedical sciences", students will be released from classes for three days to conduct experiments at the Institute of Molecular and Cell Biology, one of the research institutes housed in Biopolis, a two million square foot complex with state-of-the-art facilities.

The reactions of two student-participants are quite surprising. One student said that his "*three days* helped him realize research work was not boring...but quite exciting as you're always wondering if you've discovered anything new." A girl had this to say of her *three-day* experience: "Getting to walk in a researcher's shoes to see what they do for real has inspired me to want to be a researcher in molecular biology or zoology." If course and career decisions are going to be made on the basis of a *three-day* experience, it would be interesting to see what the rate of attrition from the science pipeline would be like years down the road. Fortunately, many of the Integrated Program schools offer more than a three-day exposure experience. The schools have begun to network with the local universities, research institutes, and industry experts to plan longer-term science research mentorship programs for students.

The problem

Given the importance of research and development in science and technology in the economic sustenance of Singapore, it is anticipated that more and more resources will be directed to the development of talents in this sector. Preparation for a more scientifically and technologically complex world requires the best possible education. The Ministry of Education (MOE) has been implementing changes to ensure that young children learn how to think critically, synthesize information accurately, and solve problems creatively. All students will have facility with computers, the ability to communicate using different media, and be familiar with the science and technology that form the foundation of the modern knowledge-based world. For students who show special aptitudes and interest in science, the MOE in collaboration with research institutes will provide more opportunities for them to have exposure to scientific research as early as possible. As mentioned, many of the top secondary schools and junior colleges offering the Integrated Program are organizing mentorship programs like the Science Research Program (SRP), Singapore's premier mentorship program established in 1988. But is a mentorship program suitable for all types of students? Are mentorship programs the most efficient way to utilize the time and expertise of the limited pool of scientists and researchers? Has the 17-year SRP been successful in meeting its objective of encouraging gifted science students to go into scientific research careers?

The program has modified its selection procedure, and seems to be moving toward a heavier reliance on tests, with the removal of the face-to-face interview in 1996, and the elimination of the use of teacher ratings in 2003. How have the changes made in the SRP selection procedure impacted the type of students that are placed in the program? These questions remain unanswered to date.

It is disquieting that so many resources will be invested in one type of intervention in the absence of rigorously collected evidence of the actual contribution of such programs. With so much at stake, it is imperative that research evidence be gathered to assess the efficacy of a mentorship program like the SRP in attracting and retaining gifted science students in science-related careers, especially in scientific research and development. The SRP has never undergone a major review in all these years, and it has never surveyed all ex-participants to find out if they are still in science.

This study seeks to explore the factors that lead young gifted students to gravitate toward science, and to find out if the SRP has been effective in meeting its objective to nurture a group of the most talented, committed and enthusiastic students to contribute to the country in the areas of scientific research and development.

Conceptual framework

This study uses Gagne's (2003, 2004) *Differentiated Model of Giftedness and Talent (DMGT)* as a conceptual framework. Gagne's model, to date, is the most comprehensive representation of the complexity of the talent development process. In his model, he makes a clear distinction between giftedness (potential, aptitudes, 'raw' and untrained abilities) and talents (trained abilities, achievements). A 'gifted' person in any of the four domains – intellectual, creative, socioaffective and sensorimotor - must be in the top 10 percent among age peers. One whose aptitudes have been transformed into systematically developed skills in a specific area of human performance, science for instance, and whose skill mastery places him in the top 10 percent of peers in his field is considered to be 'talented' in that field. By implication, Gagne's definition means that one cannot be talented without being gifted. Facilitating the talent development process are catalytic factors – intrapersonal, and environmental, which interact with learning and practicing processes and chance in a complex pattern to develop giftedness into talents. The graphic representation of the model is in Figure 1.

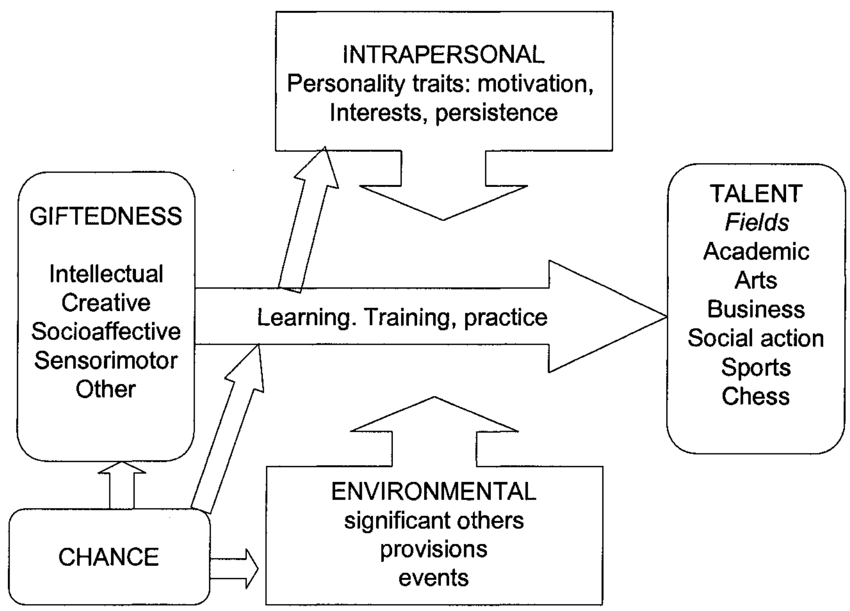


Figure 1: Gagne's Differentiated Model of Giftedness and Talent

Gagne's model has been adapted to organize this study to explore the factors that influence gifted science youth to gravitate towards science, and to find out if students in the SRP stay in the science pipeline or leave it at different stages of their talent development journey (See Figure 2).

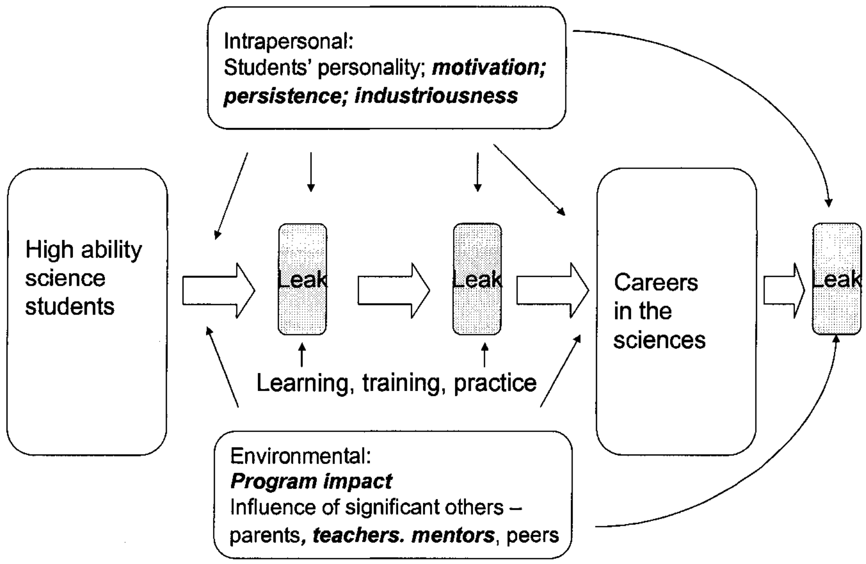


Figure 2: Gagne's model adapted for study

Definition of terms used throughout this study

<u>Giftedness</u> denotes potential, aptitudes, 'raw' untrained abilities in any domain, including intellectual and creative (Gagne, 2003).

<u>Scientific giftedness</u> refers to scientific thinking potential or a special talent to excel in the natural sciences. (Heller, 1993).

<u>Scientifically gifted students</u> in this study refer to students who have been selected for the Science Research Program on the basis of exceptional performance in math and science (distinctions for math and three sciences at Grade 10), high interest in and aptitude for science as measured by a science aptitude test (must score at least above average),

teacher rating scale as well as level of participation in science activities in secondary school (Grades 7 to 10). (M. Han, personal communication, August 24, 2004).

Talent refers to abilities that have been transformed into achievements as a result of systematic formal and informal training and practice (Gagne, 2003).

Environmental catalysts refer to external catalysts like significant persons (parents, teachers, mentors, siblings, peers); interventions like school or gifted program provisions; events like winning an award or the death of a parent; as well as the cultural milieu (Gagne, 2003)

Intrapersonal catalysts are the individual's personality and psychological traits (Gagne, 2003).

Mentor is an expert who can manifest for a mentee someone who has accomplished the goals to which the mentee aspires, offering guidance, encouragement and help, in a particular area, (like science) usually focusing on advanced projects, and exploration of work settings (Daloz, 1999).

Significance of the study

With the findings from this study, the SRP committee will have research-based data to inform decision-making related to the selection of participants and mentors, and the structure of the program. Findings will also provide IP and other schools some direction for the types of programs they could and ought to design for different types of students. In addition, the study will also shed light on qualities of effective science teachers, and this could have ramifications for identification and training of science teachers in general, and science teachers of the gifted in particular. Findings pertaining to the role of parents in the gifted science students' academic development can also be used for parent education.

The study could also be replicated for the other mentorship programs that are organized by the MOE: the Creative Arts Program, now in its 16th year, the Humanities and Social Sciences Research Program, now in its 12th year and the Leadership Development Program, now in its 10th year. It would be interesting to see if students' perceptions of desirable qualities of effective teachers and mentors differ significantly across the different domains.

It is not the intention of this study to pass judgment on those who leave the science pipeline. Although 'attrition from the science pipeline' may have negative connotations, none is intended here. In talent-scarce Singapore, it is not uncommon for people to move out of science into fields where they can make a greater impact. For instance, 13 of the 20 Singapore cabinet members have an advanced degree in math/science from top universities around the world. The premise in this study is that the gifted science students in the SRP could have majored in math/science in university, and pursued math/science careers if they had wanted to. Yet, some **choose** *not* to, and could probably be making a stronger impact in their chosen non-math/science career. The question is whether policy makers can do something about some of the factors that prompt Singapore students to leave science; not the factors pertaining to personal preference and interests, but those that are perceived by participants as 'negatively' impacting on their talent development in the sciences, and their academic and career decisions.

Synopsis of relevant literature review

Gagne's assertion that giftedness refers to innate aptitudes in different specific domains continues to be debated in the field. A few (e.g. Ericsson, 2003; Ericsson, Krampe & Heinzmann, 1993; Howe, 1993, 1999; Howe, Davidson & Sloboda, 1998) have claimed that with intensive training and support, it is possible for individuals to achieve at exceptional levels; it would be difficult to distinguish if the achievement is due to giftedness or hard work. Others (e.g. Detterman, 1993), however, claim that with the *same* amount and intensity of training and practice, what sets the exceptional apart from the others is innate giftedness. Research on eminent mathematicians and scientists has shown that their average IQ score is about two standard deviations above the norm (Simonton, 2004). In the case of exceptional science achievement, the minimum threshold level of intelligence is believed to be an IQ of 150 (Jensen, 1996). Simonton (2004) opines that an IQ threshold of 120 "represents the minimum intellect required to master the basic knowledge and techniques that constitute an individual's sample from the population of phenomena, facts, concepts, variables, constants, techniques, theories, laws, questions, goals and criteria that define the [science] domain" (p.104).

There is considerable research evidence to support Gagne's conceptualization of the talent development process. Bloom's (1985) ground-breaking study of talent development in young people delved into the developmental and educational processes that enable talented individuals to reach exceptional levels of attainment. The study has provided strong evidence that no matter what the initial characteristics (or gifts) of the individuals, unless there is a long and intensive process of encouragement, nurturance, education and training, the individuals will not attain extreme levels of capability in these particular fields" (p.3). "[T]he major value of this study is that it documents many new insights into human potential and the means by which they are translated into actual accomplishments" (p.18). Bloom and his associates described in detail the role of parents, teachers and others in teaching, motivating and supporting these individuals at different stages of the talent development process. There is no guarantee that an outstanding student of math and science will become an outstanding mathematician or scientist. During the long and arduous process of talent development, he would need the support of the family, his teachers, role models/mentors, time and a single minded devotion to this quest.

Research on eminent mathematicians and eminent scientists suggests that these people have in common many intrapersonal traits, including intense curiosity (Heller, 1993), commitment (Roe, 1953 cited in VanTassel-Baska, 1989b); persistence (Cox, 1992; Simonton, 2003); motivation and willingness to take risks (Csikszentmihalyi, Rathunde & Whalen 1993); and openness to experience (Simonton, 2004).

Many gifted science students and eminent scientists have voiced negative attitudes toward education (Bloom, 1985; Csikszentmihalyi et al, 1993; Simonton, 2004). But those who had positive experiences appreciated the freedom to follow their own inclinations, the great amount of time to do independent work, the ability to choose their course of study/projects, and opportunity to participate in out-of-school activities, including non-science related ones. Simonton (2004) asserts that a sample of the scientist's knowledge and expertise comes from the curriculum in school; yet formal science education can sometimes adhere too closely to traditional ways of viewing phenomena. The successful talented scientist must therefore be able to strike a balance between "mastering a domain and being mastered by a domain" (p.127). Effective science teachers can play an important role in helping gifted science students find that balance.

The role of the school is best explicated by Brandwein (1995) whose work on how schools can develop scientific giftedness proposes an ecology of achievement that can offer youth the opportunity for their special endowments to flourish. The young who seek careers in science or technology need inspiring teaching and learning in an "educational ecology of achievement." In such an ecology, instructional learning becomes a "system for discovery of abilities through achievement, through the self-identification of capabilities by the young...Envisaged and conceivable are such programs that will validate themselves as a means of natural assessment of growth in science talent" (p.xi) . Self-selection, to Brandwein, is a more effective way to uncover science talents.

Since children come from different types of homes that might nurture or impede the talent development process, the school could be a venue where ***all*** children can find "their own capabilities, learning how to discover for themselves and revealing portraits of intellective and non intellective abilities. Science potential may then be discovered or confirmed through performance in programs through instructional learning"... (p.xi) And to identify the exceptionally talented who might tend to choose a career in science, Brandwein believed that science talent may be measured by the "originative work" produced by students. The behaviors of the scientist-to-be will emerge, and the achievement will reflect the "philosophy, observable behavior and the methodology of science" in context. Brandwein's model seems to place greater importance on the role of the school in providing the opportunity for the child to find out if he is science-prone, and to allow the science-prone child to subject himself to rigorous science programs voluntarily to see if he has science talents. Whether or not the child responds to these activities depends on his predispositions.

Contribution to the field of gifted education

The research on the effectiveness of mentorship programs seems to focus predominantly on mentorships for at-risk populations, including individuals from disadvantaged homes, minority ethnic groups, and in the case of science, for girls and women to encourage them to enter, and remain in the field. Where it is focused on gifted populations, it tends to be limited to younger students who participated in programs where projects are not limited to science. For the few studies on high school students, claims that have been made about the success of mentorship programs have cited little evidence that is specific to mentoring. The studies tend to focus on outlining possible programs, rather than looking at impact and benefits of the mentoring experience (Schatz, 1999). There is need for more follow-up studies of gifted students who have participated in mentorship programs to analyze their impact. This study, which focuses on high school students involved in a year-long mentorship program emphasizing high level science research, will contribute to the research base on the effectiveness of mentorships as a form of intervention for gifted students at the high school level in the domain of science.

There are also very few longitudinal studies on gifted populations. While the Study of Mathematically Precocious Youth (SMPY) focuses on exceptionally gifted math students, the nature of the intervention is acceleration. Perhaps Subotnik and Steiner's (1995, 2002) research on Intel (formerly Westinghouse) semi-finalists and finalists comes closest to a longitudinal study of gifted science students; however, the focus was not at all on the impact of an intervention. This cross-sectional study of three cohorts of SRP participants can contribute important insights to the field of gifted education and talent development on the *type* of gifted science students who would benefit from a mentorship program like the SRP. It also sheds some light on the effectiveness of mentorship programs as an intervention to nurture science talents, and support the retention of science talents in the sciences.

Participation in this program was not dependent on the ability to pay. Does this mean that gifted science students in the SRP are more likely to come from more different socio-economic and home backgrounds? Or is it the case that students from professional and middle class homes are the most likely to avail themselves of such opportunities as mentorships, as suggested in the literature? This study may also help the field understand the power of sustained intervention for students from more modest backgrounds.

Conclusion

This chapter has laid out the rationale for this study on the talent development process of a sample of Science Research Program (SRP) participants from Singapore. It also gave a brief synopsis of relevant literature reviewed as well as the significance of the study. The following chapter will be a review of the literature covering the major issues relevant to this study.

Chapter 2

Review of the Literature

In this chapter, literature pertaining to different conceptions and models of talent development will be reviewed. Emphasis will be placed on research that explore the various variables in Gagne's *Differentiated Model of Giftedness and Talent (DMGT)*, and the role they play in facilitating the conversion of potential and gifts to talent. In particular, research on intrapersonal and external catalysts will be cited to amplify the talent development process in Gagne's model. Other strands of literature to be reviewed include effective science education for students with aptitude in this domain, mentorships, the issue of gender imbalance in high level science courses and careers in the science field as well as the high rate of attrition from the science pipeline.

Conceptions and models of talent development

Talent development, to Clark (2002), involves the deliberate and planned effort to provide children with an enriched and responsive learning environment both at home and at school so that all of their talents and abilities will have the opportunity to develop to maximum levels. Treffinger (1998) takes it further by including gifts in the definition, although to him, "talent emerges from aptitudes and sustained involvement in areas of strong interest or passion. It is not simply natural endowment or a 'gift'...[It].arises from the interactions of four important components: characteristics of the person, the context in which the person functions, the content domain or area of expertise in which the person acts, and the operations, processes, tools and strategies the person employs..." (p.753). In his seminal book, Bloom (1985) defined talent as "an unusually high level of demonstrated ability, achievement, or skill in some special field of study or interest..." His study found evidence "that no matter what the initial characteristics (or gifts) of the individuals, unless there is a long and intensive process of encouragement, nurturance, education and training, the individuals will not attain extreme levels of capability in these particular fields" (p.3).

What can be discerned from these definitions is the notion that talent is demonstrated ability/achievement in any domain, and at the maximum level it is sustained, and that talent development is a process that has to be fostered. A survey of earlier definitions reveals that talent used to be conceived as unusual ability confined to *non-academic* lines, and referred specifically to performance rather than potential (Callahan, 1997). This nebulous conception of talent became more hazy when the Marland (1972) definition started using 'gifted and talented' as a unitary concept, a use perpetuated by the likes of Tannenbaum (1996) who used the terms interchangeably as he found the distinction between gifted and talented 'unhelpful'. Tannenbaum (2003) believes that besides intellect, a child's future is shaped by the interaction of his personal attributes and his surroundings. In his sea star model linking promise (aptitudes) and fulfillment (accomplishment), five factors interact to produce excellence. All five factors – superior general intelligence, distinctive specific aptitude, non-intellective traits, challenging and facilitative environment and chance – must be present at a minimal level. A serious deficiency in any of the five factors would render attainment of excellence not possible. It can thus be seen that without making a distinction between gifted and talented, Tannenbaum has also postulated that a process is involved for the transition from promise to accomplishment, a process involving individuals interacting with, and responding to their surroundings.

The interchangeable use of the terms gifted and talented is not uncommon. According to Heller (1993, p. 139), "scientific *giftedness*...can be defined as scientific thinking potential or as a special *talent* to excel in [natural sciences]." This seemingly straightforward definition, however, would be problematic, when seen against Gagne's (2003, 2004) *DMGT,* on which the conceptual framework for this study is based. In his model, Gagne distinguished giftedness from talent. To him, giftedness denotes potential/aptitudes, 'raw' and untrained abilities. These gifts can be in any of four domains: intellectual, creative, socioaffective and sensorimotor, i.e. it can be in both academic and non-academic domains. A gifted person in any of these domains must be in the top 10 percent among age peers.

Talents, on the other hand, refer to trained abilities and achievement. Talents also denote the transformation of aptitudes into systematically developed skills in a specific area of human performance, science for instance. An individual whose skill mastery places him in the top 10 percent of peers in his field is considered 'talented'. Gagne's definition, by implication, means that one cannot be talented without being gifted. A gifted person who is not willing to engage in systematic learning and practice will not see his gifts translated into a talent area. Gagne described the talent development process as the continuous interplay of the individual's characteristics and catalysts in his environment. The intrapersonal catalysts refer to the individual's dispositions and psychological traits while the external catalysts refer to persons – parents, teachers, mentors, peers, siblings; interventions like gifted program provisions; events like winning an award or getting hurt in an accident, as well as the cultural milieu that can facilitate or impede the talent development process. Of all these environmental catalysts, Gagne (2003) cited research that suggests that the "lion's share of environmental influences" are attributed to significant persons (p.65). A closer examination of the *DMGT* also reveals that Gagne accorded chance a fairly important place in his model because in "all the causal components of the *DMGT*, there is some degree of chance…except the LP [learning and practicing]" (p.66). See Figure 1 on p.8.

How can Heller's definition of scientific giftedness fit into Gagne's model? If the individual does not have the scientific aptitude, there is nothing that the external catalysts can do to help the individual become 'talented' in science. No amount of learning and practice or programmatic provisions or persistence can propel a person without the requisite gifts to perform at the top 10 percent in his field – the road to excellence, in Gagne's model, requires more than just "practice makes perfect". Csikszentmihalyi (1992) also agrees that knowledge and heuristics alone cannot account for the occurrence of a creative product and/or idea. He listed four other components that must be considered to explain creativity: the person's interest in the domain, perseverance, dissatisfaction with the status quo, and the environment which sets the standards and decides what types of creativity to support.

Bloom's (1985) seminal study on talent development, however, shows that gifts are a necessary but *insufficient* factor in the talent development process. How else can one explain how it is possible for people with *lesser* gifts to exceed those who are *better endowed* with raw abilities in achievement and eminence? *Other* factors must be at play to account for the achievement of the 'highest level' of *some* gifted people.

Bloom's study

In *Developing Talent in Young People,* Bloom (1985) stated that "the major value of this study is that it documents many new insights into human potential and the means by which it is translated into actual accomplishments" (p.18). This study is valuable in yet another way – it is a landmark research study that delved into the developmental and educational processes that enable talented individuals to reach exceptional levels of attainment. The study describes in detail the role of parents, teachers and others in teaching, motivating and supporting these individuals at different stages of the talent development process. Bloom's study provides some research evidence to support Gagne's *DMGT,* especially in explicating the role of the intrapersonal and external catalysts that help to translate potential into actual high level accomplishments.

Bloom's talent development model had four distinct phases: First is the individual's exposure to the area of talent in the home environment, before formal instruction begins; second is the early years with the first teacher in the talent field who tries to make instruction fun and enjoyable; the third phase is the middle years with instruction provided by more advanced teachers who expect the individual to master knowledge, skills and techniques; and in the final phase, the individual works with master teachers who demand total commitment of time and energy, and nothing less than the best of them.

Specifically, how is potential translated into extreme levels of capability? In the study of 125 talented individuals in six domains, Bloom found that the parents (home) and the teachers (*not* school) played pivotal roles in the developmental and educational process.

Role of the home

In the pre-formal instruction phase, the home was the most important catalyst for the child's development in the talent field. Bloom (1985) found that a common characteristic of the parents of the talented individuals in his study had a very child-centered approach to nurturing their children. Without exception, they were willing to devote time, resources, and energy to developing their child's talent. Parents of these talented teens modeled intellectual behavior and the ethic of hard work. They valued academic achievement and success and transmitted to their children values like working hard, doing well, persistence, and set high expectations for their children. Even when they were in elementary school, most of the children were aware that they were going to college. There was emphasis on self-discipline, doing one's best, and satisfaction of accomplishment.

The parents encouraged their child's talent by responding appropriately to the child's interest in the talent field. In the case of the mathematicians and research scientists whose first signs were curiosity, questioning, wondering, wanting to know more, parents encouraged and nurtured these traits. The way the parents responded shaped their children's subsequent development. Parents did what they could to satisfy the children's curiosity. Instead of providing the answers, they taught the children how to find the answers themselves. Parents modeled different ways of accessing information, and children soon began to value the process of inquiry. They preferred to figure out the answers rather than be told. The parents were conscious about directing their children's interest because they did not want them to get involved in activities they did not particularly like. So parents encouraged the children to read, and develop their own interests, and shared with them the excitement of discovery.

Parents also provided material support. Many children remembered getting what they asked for – mechanical projects or building models to work with. It is important to note that parents saw these activities as hobbies, pleasurable in and of themselves. If the children preferred to play or work on their own, and many of them indicated this preference, parents respected their wish and did not force them to socialize with other children.

Family discussions were an important feature of the child's development in the early years. At meal times, the child got to initiate topics of discussion, although parents were often selective in the topics they were willing to discuss; in cases where one or both parents were engaged in scientific work, they would talk about their pursuits.

Parents played a different role when the children were in junior high or high school. Parents took an interest in their progress, and provided moral and material support. They ensured that the child would have the materials necessary for experimentation; they worked with children on their projects and discussed topics of interest with them; parents would actively seek out special opportunities to supplement school – summer programs, or early admission to college. Parents emphasized doing homework, and always encouraged children to do extra credit work. Parents who had been to college were role models. As the children's curiosity became more focused on mathematical and scientific interests, parents made sure there were resources at home to support the children's intellectual curiosity. Bloom found that in half of the mathematicians' homes, *Scientific American* was available. Most homes subscribed to talent-related magazines and had talent-related materials and supplies to support the child. Even as they supported and nurtured their children's development, the parents remained unobtrusive. When it was time for the children to think of career options, the parents wanted them to feel free to make their own choices. This role of parents has been supported by subsequent research studies, some of which will be reviewed in a later section.

Role of teachers

Just as the role of the home changed over the course of the talent development process, so did the role of the teacher. Different qualities of teachers seemed to be more suitable for the child at different stages. In the case of the young mathematicians and research neurologists, they were introduced to formal mathematics in junior or senior high school, when mathematics was taught four hours per week. The initial teachers were those who helped their students see the larger patterns and processes in mathematics, and encouraged students to 'discover' these ideas and processes for themselves. Such teachers were more open to students finding and using alternative methods to problem-solving. The mathematicians were particularly appreciative of teachers who gave them permission to learn math on their own from the math text books. To the young mathematicians, the joy of discovering new ways of solving a problem was more important than receiving a good grade. The research neurologists had a similar view of school. To them, school was rather a 'drag'. What was "intellectually exciting was what you did on your own" (p.377). What characterized this stage was the fun and joy of learning. Teachers encouraged and motivated students by acknowledging their progress. Participation in competitions which entailed intensive practice gave the young mathematicians much pleasure. Because the students enjoyed their math and science assignments and projects, parental pressure was not necessary. Students rarely approached parents or others for help with their work.

As the student receives recognition for his special talent, his commitment to the talent field increases. This usually happens when the student is in his teens. At this stage, the student is likely to need a mathematics/science teacher who is connected to a college or university math/science department. Parents would actively seek out these teachers for their children. These new teachers had exacting expectations of their outstanding students – and expect them to reach very high levels of attainment. The teachers rarely gave these talented younger students more attention in class. At this stage, the students continue to do a good deal of independent learning on their own from books and other sources. They discuss what they have read with other students, and their teacher, who would in turn refer them to the works of an outstanding mathematician/scientist on topics of interest to the students. By this time, the students are expected to place the talent field above all other courses and activities. Teachers have supplanted parents as the main motivator as the students need less and less of parental support. The young mathematicians and aspiring scientists begin to develop intrinsic motivation for their aspirations in the field.

In the later years, the talented youth, and his parents and teachers would expend energy to search for a master teacher for the youth. The youth would have to prove himself worthy before the master teacher was willing to accept him. And what was expected of the talented budding mathematician/scientist? He had to be totally committed to the domain, and accept fully the teacher's demand for perfection. He must be prepared to solve problems that had never been solved before. The student worked very closely with the master teacher, consulted him, and observed him at work, to see how he conducted creative research in math. The students also learned novel ways of problem finding and problem solving by interacting with other outstanding students. They would participate in public events – competitions and seminars, and benchmark their performance against that of equally outstanding students. The master teacher would give them critical feedback on their performance, and advice on how to perfect aspects of it. This exposure to the highest level of competition and performance standards helped the talented mathematician/scientist to determine what and how much more he has to, and is prepared to do to attain the highest level of performance. By this stage, the motivation for him is mainly internal, and related to his career aspirations in the domain of talent.

It can thus be seen that the talent development process is a deliberate, purposeful and arduous one. At each stage, parents, teachers and the individual have to take deliberate steps to transition to the next level. The style and substance of the learning and teaching process is distinct at each stage. There is no guarantee that an outstanding student of math and science will become an outstanding mathematician or scientist. During the long and arduous process of talent development, he would need the support of the family, his teachers, role models, time and a single-minded devotion on this quest. Undergirding the process is the assumption that the individual has the commitment, motivation, persistence and perseverance to undergo the journey, with the support of parents, teachers and significant others. For if the child was not willing, parents and teachers would not have devoted time and resources to his nurturance.

Brandwein's views on scientific talent development

A discussion of the scientific talent development process would be incomplete without reference to Brandwein's works on how schools can develop scientific giftedness. Brandwein proposes an ecology of achievement (1995) that offers youth with the opportunity for their special endowments to flourish. The young who seek careers in science or technology need inspiring teaching and learning in an 'educational ecology of achievement.' In such an ecology, instructional learning becomes a 'system for discovery of abilities through achievement, through the self-identification of capabilities by the young...Envisaged and conceivable are such programs that will validate themselves as a means of natural assessment of growth in science talent" (p. xi). [T]he young will find their own capabilities, learning how to discover for themselves and revealing portraits of intellective and non-intellective abilities. Science potential may then be discovered or confirmed not only through performance in programs through instructional learning, not only from the varieties of evidence gleaned through assessments of science proneness and talent, but also – and most importantly, through the originative work that is their criterion sample". (p.xi).

Self identification of science proneness

To Brandwein, in the primary school years, formal testing is unnecessary as a means to pre-assess ability, or for self-identification by the young. Even before the talent pool is developed, young children should have the opportunity to participate in instructional learning that would enable them to identify themselves as science-prone. In such a system, observation/talent spotting becomes critical. Where opportunities are open to every child, very soon, differences in expression of abilities appear. Observations of teachers, peers and parents may lead to the consensus that a certain child may or may not be science-prone. The self-defined science-prone may then self-select to further participate in differentiated curricular programs in science or mathematics. Brandwein's argument is that if judgment about a child's eligibility to participate in special programs has to be made, that it be made ***after*** the young have had the chance to identify themselves for it, and their choice is followed by consistent science-specific works, because then we would have a "better picture of in-context potential signaled through performance" (p. vx). To identify the exceptionally talented who might tend to choose a career in science, Brandwein believed that science talent may be measured by the originative work produced by students. The behaviors of the scientist-to-be will emerge, and the achievement will reflect the "philosophy, observable behavior and the methodology of science" (p.xix). For students to commit to originative work, it takes persistence, dedication and will. Two major characteristics of young students who 'volunteer' to participate in the experimental paradigm, which includes research and independent work after school hours, are "their *manifest free-floating doubting* of present explanations of phenomena and, the persistence with which they pursued the inquiry" (p. 124).

Brandwein emphasized these two traits – questing (defined as a 'notable dissatisfaction with present explanations of the way the world works', p.124) and persistence (which includes consistent attention to inquiry, willingness to undertake study of instructional materials, p.124) as good indicators of science talent. Hence, his operational definition of science talent is as follows: "Science talent in high school students is demonstrated in originative work rooted in the self-testing and self-correcting code of scientific inquiry" (p.xxi). While Bloom accords parents the role of exposing the child to exploratory activities so that the child's talent might emerge, Brandwein's model seems to place greater importance on the role of the school in providing the opportunity for the child to find out if he is science-prone, and to allow the science-prone child to subject himself to rigorous science programs voluntarily to see if he has science talents.

Ways to identify and nurture science-prone learners

What kind of programs will attract the science-prone to self-identify? Do these programs have to be restricted to *science* activities? There is research evidence of students who avail themselves of advanced math and science courses earlier and go on to major in these at university and achieve at high levels of accomplishment (Cross & Coleman, 1992; Webb, Lubinksi, & Benbow, 2002). In their study of residential schools of mathematics and science for academically talented youth, Jarwan and Feldhusen (1993) concluded that the educational programs and curricula they observed in those schools were of very high quality and could readily serve as models for other school programs for the gifted. They stressed, however, that "if the curriculum stresses mathematics and science, then the identification-selection system should find youth with particular strength, precocity or talents in those areas" (p.4). Research emanating from the University of Iowa on the participants of the Study of Mathematically Precocious Youth (SMPY) continues to buttress the evidence base of the highly positive effects of acceleration, especially for students gifted in mathematics and the sciences.

The College Board's Advanced Placement (AP) courses have also been advocated for self-identified science-prone students. College-bound students who choose AP coursework have benefited from the fast-paced course work which requires students to exhibit analytical, interpretative, synthetic and evaluative skills to perform assigned tasks at high levels (VanTassel-Baska, 2001). In VanTassel-Baska's opinion, "AP students acquire core knowledge used by professionals and the tools to inquire about how knowledge is generated in a given field. Such an approach fosters in gifted learners a deep level of understanding about 'how the world works' and provides a starting place for creative original work" (p.127). Additionally, efforts to prepare students for advanced study often stimulate improvements in prerequisite courses (National Research Council, [NRC], 2002), a development that benefits a larger number of students.

There are of course some educationists who are not in favor of AP. Callahan (2002) for instance is concerned that AP teachers, in their anxiety to cover content for the examination, might not be able to enthuse students. Her fear that AP might be perceived as an extrinsic motivator and kill student interest in science is probably unfounded. The mathematicians and research neurologists in Bloom's study (1985) had taken "as many advanced courses" as possible *and* a few of them also went on to self-select for independent projects to pursue their scientific interests and do original work. Milgram and Hong's (1999) research has shown that students' pursuit of activities which they do for their own enjoyment and by their own choice were a valid predictor of their career accomplishment as adults. Albert (1993) also specifically mentioned informal educational experiences as contributing to the development and realization of talent.

Apart from the *type* of school intervention, there is also some debate about breadth of programs. There are some researchers who feel that science-proneness could be identified *outside* the domains of science and mathematics. A myriad of activities in the classroom, and the real world provide opportunities for students to learn about math and science concepts (Fu, 2005; Ginsburg, Balfanz & Greenes, 1998). According to Miller, Steiner, & Larson (1996) students can use literature to verify predictions, confront and correct their misconceptions about science and make inferences. Moss and Hendershot's research (2002) showed that allowing students to read nonfiction trade books in the language arts class can deepen student interest in content related topics, in science for instance. Innamorato (1998) suggested that authentic scientific creativity is a meshing of artistic and scientific abilities, and made a case for the inclusion of artistic activities in gifted science programs. Root-Bernstein and Root-Bernstein (2003) emphasize the importance of intuition in scientists' creative work, and stress the importance of experiential learning as "intuition results from doing things, not passively learning about them" (p. 383). Their quotes by two eminent scientists illustrate clearly the importance of intuition. To Poincare, arguably the greatest mathematician of the 20th century, "It is by logic that we prove, but by intuition that we discover" (p. 379). Barbara McClintock, Nobel laureate put it differently: "When you suddenly see the problem something happens that you have the answer before you are able to put it into words. It is all done subconsciously...You work with *so-called scientific methods to put it into their frame after you know"* (p. 378, emphasis added). In her analysis of factors explaining high abilities of Nobel laureates, Shavinina (2004) concluded that the creative functioning of Nobel laureates is determined in part by their "intuitive processes, [and] subjective feelings and beliefs..." Teaching 'certain' (as opposed to 'uncertain') science (Jenkins, 2000) and the scientific methodology cannot develop nor nurture these intangible qualities in budding scientists. It is clear that the science-prone are unlikely to surface through canned experiments and didactic labs and tests of 'scientific facts'. The research neurologists in Bloom's study (1985) did more math and science courses than their peers did, but "they were not dedicated to a life of science..." These neurologists would never have been identified in their high school as likely to go far in the field of medical research (p. 383). As students, the neurologists were involved in a mélange of activities. Active involvement in *other* activities could as likely if not more likely to lead the science-prone to self-identify. One neurologist recalled how his fishing trips led him to science: "At first, it was something that I did with my father for fun. And then it became more of a thing I approached with scientific zeal. I was interested in the way fish lived, what part of the lake they lived in, and what they liked to eat. Because it related so much to my interest, I thought I wanted to be a marine biologist." (p. 362).

It would appear that a combination of science and non-science programs in and beyond the classroom, carefully designed to engage students so that they would self-select to be involved in original work, will both help to uncover science talent (Brandwein, 1992). Whether or not the child responds to these activities depends on his 'predispositions'. In this regard, Bloom, Gagne and Brandwein seem to agree – that some intrapersonal, psychological traits are necessary for the talented individual to bring his potential to fruition.

Research evidence

How well does research support these talent development models? What is the relative importance of the catalysts involved in the talent development process? Which are amenable to intervention, and which are not? What are other researchers' views about these different conceptions of the talent development process? This next section attempts to capture major views in the literature on these questions.

External catalysts: Role of Teachers

In the Bloom (1985) study, the three types of teachers at different stages of the talent development process seem to apply more to music, sport, and the arts. The mathematicians and neuroscientists' recollections of their teachers do not seem to fit in the stages. Most of the mathematicians, for instance, found their elementary school experience 'quite ordinary' (p.289; p.366). The curriculum was not an influence, and school did not seem to have anything to do with their ambitions or hopes. Rationalizing that "skills required for research mathematicians were qualitatively different from skills learned in arithmetic", the researchers opined that the most significant aspect of schooling was that "the independent nature of the mathematician was established more firmly" (p.292). The 'best' teachers were those who supplied the mathematicians with books and materials with which they could work on their own. The situation did not seem to have improved at the high school level. Most of them were unable to recall any extraordinary high school teacher. They viewed their experience as ordinary. "Nothing that went on in high school was more interesting than what they were learning on their own" (p.302). Of the twenty mathematicians in the study, sixteen did independent work in high school on topics that were ahead of grade level, or they analyzed board games. Apparently, they felt that the content was less significant than the fact that they were working on their own (p.301). For those who had difficulties in school, they attributed them to "poorly trained teachers and/or methods of instruction with which they were uncomfortable" (p.305). Based on the experiences of the mathematicians in this study, it appears that these mathematicians had persevered in the mathematics track *in spite* of their teachers.

The picture painted by the research neurologists was no different. They had few memories of their school experience because these were 'inconsequential'. High school science classes were perceived as "another chore of going to school" (p.377). One neurologist had such bad memories of school science that he described it as 'deadly'. They found stimulation in the independent projects they undertook. What these talented youth said about the value of independent work echoes Darwin's claim that "I consider that all I have learned of any value has been self taught" (Simonton, 1999, p. 120). Perhaps, at the high school level, Bloom's notion of 'falling in love' with the talent field is not necessarily facilitated by active teaching on the part of math and science teachers; it is 'leaving the student alone' to do independent work by himself that leads him to discover the joy that math and science can offer.

In their research on talented teenagers, Csikszentmihalyi, Rathunde & Whalen, (1993) found that they are unusually sensitive to the quality of teaching in their talent areas. They seem to be able to share vivid details about teachers they like and dislike. It was reported that "most math teachers haven't been that great" (p.183). They do not share students' interest in the everyday applications of math, and some of them reportedly just "sit at the overhead projector and write theorems" (p.183). Students are left unsatisfied as math teachers deflect questions about applications with "don't worry about that right now" (p.183). For three quarters of the time, talented teenagers in the survey reported from the classrooms that they did *not* want to do what they were doing. Whalen (1998) wrote that while scientifically talented teenagers reported high levels of concentration while doing school math and science, they felt 'below average' levels of enjoyment and involvement. Csikszentmihalyi (1996) found in his study of one hundred creative individuals that the eminent persons did not have positive memories of their secondary schools. Even Nobel-Prize winning physicists and chemists had hardly a good word to say about their schooling. Veltman (2004) remarked that successful physicists like Glashow, Weinberg, and Schwartz who were students at the Bronx Science High School could not recall any particular teacher, but attributed their development to the presence of other gifted students.

However, the teenagers who have favorable memories of teachers are intrigued by those who show enthusiasm for their subjects, are 'fired up and excited' about what they are teaching, and model interest in teaching and a professional life. Their genuine interest inspires students to consider the intrinsic reward of exploring a domain of knowledge (p. 184). The few mathematicians in Bloom's study who had positive experiences also remember fondly teachers who liked what they taught. What one student said of his geometry teacher is probably typical of how the other students felt: "I think she was a very traditional teacher. Her approach was completely traditional, but the point was that *she obviously enjoyed the subject* and she knew what she was talking about…If you want to have a positive experience, you need to have an interpersonal type of relationship with someone who succeeds in creating a positive experience….The point is that you tune in to the person. The function of the teachers is to make things interesting, to produce positive motivation, to serve as an example…" (Bloom, 1985, p. 307). The neurologists too cherished memories of science teachers who knew 'a great deal' about what they were doing, were enthusiastic about it, and had high standards of excellence, which the students found challenging (p. 376).

These findings confirm those of a study done by Casserly (1974) three decades ago. Girls who were enrolled in Advanced Placement (AP) math and science classes in spite of sex-typing in school cultures, enrolled in these classes because of the 'infectious enthusiasm' of their AP teachers. "He just lives chemistry…I mean he loves it. And he gets such a kick out of teaching it, you don't mind working for him…" "You just know he's doing exactly what he likes best…He **cares** what we learn…" (p. 153).

Good teachers, according to the teenagers surveyed by Csikszentmihalyi et al. (1993) are those who help students with skills but let them develop their own style. Such teachers are attentive to freedom – they create opportunities for students to tailor learning situations to their own interests and styles of learning, and pace. They support students who have to grapple with personal problems. What makes a teacher influential and memorable, according to Whalen (1998) are a teacher's "rigorous care for their students" (p.27), high standards and expectations and a commitment to support student effort. Such teachers also model a contagious enthusiasm for learning, and for the discipline.

Bloom's point about the importance of advanced teachers who could take students to the next level in mastering knowledge of the domain, and perfecting techniques, on the surface, does not seem to apply to the math and science teachers. Students do not seem to be affected by the teacher's knowledge (since most talented students reportedly prefer to do independent work). In his description of 'flow' teachers, Whalen (1998) made no reference to the need for such teachers to have a solid grasp of the subject. He said such teachers gave students choice, and created opportunities for students to direct their own learning, allowing them space for struggle. It seems students are more affected by the teacher's attitude towards the domain, and it is more important that the students *like* the teacher. Glass (1996), however, would contend that only teachers with sufficient expertise would dare to give students choice, and open-ended independent work where the emphasis is on recognizing problems, offering hypotheses, seeking solutions and defending conclusions. Only teachers with deep content knowledge can motivate gifted students in science to develop to the point where they can carry on original, independent research. It would seem that deep content is a non-negotiable for teachers of gifted science students to be effective, and this is implicit in students' comments about effective teachers.

Csikszentmihalyi et al. (1993) found that the toughest teachers were the most respected, a refrain of Bloom's mathematicians and neurologists (1985). Teachers who provide clear and relevant feedback help learners gain control over the trajectory of their own development. Teachers have high expectations, and convey these expectations in ways that help students improve further. They would not settle for anything less than the best. For teachers to be clear in their teaching, and to provide relevant feedback on student performance, teachers would have to know their content well. Feldman (1991), however, pointed out that experts are not necessarily the most sensitive or innovative teachers. He alluded to the importance of a match of temperament and intellectual style between the teacher and the talented individual. Perhaps in the pre-high school years, content expertise is less important than affective qualities.

Csikszentmihalyi and associates (1993) wondered whether we are asking too much of teachers who are after all not practicing mathematicians and scientists. Modern schooling and the standardized curricula serve to de-personalize the relationship between teachers and students, and emphasizes instead external mass performance standards. The curriculum is 'insulated' from the interests of the teacher.

VanTassel-Baska (1989b) seemed to concur that the influence of K-12 schooling may be an impediment to talent development. Grossman (2002) lamented that in spite of studies showing the effectiveness of engaging students in active problem solving as scientists do, teachers continue to emphasize rote memorization, producing high school graduates who are not competent in, and have little enthusiasm for mathematics and science classes. Brandwein's advocacy of an ecology of achievement can perhaps be better understood in this context. His reference to the 'activating' factor encompasses the role of the *school* in providing a conducive environment that would augment the talent development process (1992, p.126) by stimulating inquiry and discovery for all students, and to provide more opportunities for the more advanced learners to inquire and discover at more sophisticated levels. Several Nobel laureates in Csikszentmihalyi's study (1996) mentioned that their vocational interest started when a teacher asked them to set up a lab after school. The most formative influence of schools appears to be in the realm of extra-curricular activities, where they had been invited to participate in out-of-class opportunities. This was also true of the mathematicians and research neurologists in Bloom's study (1985).

At the higher, post-secondary levels, how are math and science teachers and classes perceived? Are the instructors at this level perhaps the ones who are more likely to fit the role in the Bloom model? Seymour and Hewitt's (1997) study of 335 college students in seven college campuses who switch (54.6%) or stay (45.4%) in science, mathematics or engineering programs provides interesting insights into science teaching at the college level. Most of the students, including those who did not switch, found the science, mathematics and engineering programs too demanding, boring and lacking relevance. An engineering student said it was "a hard field...It's risky to study it, I think for your ego, and friendships suffer" (p.103). A student who quit the mathematics program found it too confining: "...it's not exciting enough to allow you to put on blinkers as far as the rest of the world is concerned..." (p.60). Subotnik & Steiner (1995) reported that men and women have described physics content as "rules applied mechanically to a set of problems embedded in a distastefully competitive environment" (p.55). There is a ring of truth to many students' complaints that faculty make the courses harder than they need to be, according to Shulman (quoted in Grossman, 2002), who made this observation: "It would appear that the faculty's goal is to limit the number of majors to the few hardy souls who survive the introductory courses" (p.1). There was also the perception that academic departments at major research universities erect high barriers to entry around their fields. Seymour and Hewitt's (1997) subjects were also dissatisfied with the lack of relevance of the mathematics, science and engineering classes. They felt that the narrowness of the courses made it difficult for them to relate to the real world, and one student who stayed on in engineering remarked that he could not find a professor "that was even thinking that [personal relations] had anything to do with engineering" (p.181).

A six-year longitudinal study of undergraduate women in engineering and science at the University of Washington (Brainard & Carlin, 2001) revealed that among the most common reasons for not persisting in science and engineering were "other majors are more interesting, lost interest in science and engineering, conceptual difficulties, low grades, rewards not worth the effort and poor teaching" (p. 34). Even for women who did persist and stay in the science and engineering program, they perceived as barriers to persistence "lack of self confidence, feeling intimidated, isolation, and lack of interest" (p.33). So, it would appear that at the higher levels, both 'teachers' and 'school' did not seem to be instrumental in the talent development of science-prone students.

These descriptions about science teaching are not unique to the American situation. A High Level Group (HLG) in the European Union submitted a report on science teaching and recommended that university curricula should be less theoretical and reflect more directly on current societal needs (p.8). The HLG also found that "School science is often detached from everyday life and work experience. Better links are needed with the real world of science. More hands-on experience is necessary especially in primary and secondary level courses, which should be designed to meet the needs and interests of young people" (*Europe needs more scientists: EU blueprint for action,* Press release, April 2, 2004).

So far, the K-16 experiences of many talented students probably explain why such a small number of such individuals go on to achieve at peak levels. For those talented scientists who do, like the laureates in Zuckerman's study (1992), the role of the 'master teacher' is undeniable. Even at this level, it seems it is not the knowledge of the master that is important. Zuckerman quotes a Chemistry laureate's description thus: "It's the contact; seeing how they operate, how they think, and how they go about things. It's learning a style of thinking…" (p.163). The masters who were role models, brought out the best in the apprentices, and critiqued their work. They socialized their apprentices into the culture of science, and prepared them for their place in the upper echelon of the elitist science hierarchy.

Intrapersonal catalyst: Role of the individual

The question remains: What *types* of individuals can reach a stage of development to benefit from the mentorship of a master? Given the rather dismal depiction of the K-16 learning situation in general, before an individual can reach the level to apprentice himself to a master, could it be that the individual plays a more important role in the talent development process as suggested in Brandwein's and Gagne's models? What essential attributes do such individuals possess to enable them to overcome the seemingly insurmountable odds? Does it depend on how hungry the individual is in his quest? How prepared he is to make sacrifices? Does he enjoy his talent field sufficiently to devote himself to the single-minded pursuit of his goal and aspirations? How persistent is he on the talent development journey to actualize his promise? Therefore, are intrapersonal factors more important than people's intellectual aptitude or formal learning opportunities?

In the field, there are some researchers (Howe, 1999) who believe that innate abilities are not important in talent development, or that extraordinary levels of accomplishment are possible for individuals who do not necessarily show early promise (Sosniak, 2003). However, in his study of people who overcome negative circumstance and succeed against the odds, Piechowski (1999) concluded that "lack of general intelligence and aptitudes that form a talent" cannot be overcome. Indeed, there is general agreement that a threshold level of aptitude is necessary for eminent accomplishment, and this threshold varies from domain to domain. In the domain of science, Simonton (2004) estimates the threshold to be an IQ of 120. Gotffredson (1999) believes that individuals with IQ above 125 can essentially train themselves, and few occupations are beyond their reach mentally. Jensen (1996), however, would contend that in the case of exceptional science achievement, the minimum threshold level of intelligence is an IQ of 150.

Research studies of 'successful' talented individuals who have achieved at exceptional levels of performance have consistently shown that beyond the threshold level of intellectual aptitude, these individuals possess certain common traits, regardless of their varying circumstances. Roe's study (1953, cited in VanTassel-Baska, 1989b) of male scientists found that all of them had a 'driving absorption' in their work. McGrayne (1992) wrote that the women science laureates she studied had survived in science because "they were passionately determined and in love with their work" (p.5). Cox (1992), in her study of the early mental traits of 300 geniuses, concluded that the traits that "are diagnostic of future achievement" are an "unusual degree of persistence, tenacity of purpose, perseverance in the face of obstacles, ...and vigorous ambition expressed by the desire to excel" (p. 54-55). Simonton (2003) went so far as to assert that Cox felt persistence was more critical than intellectual ability in determining if an individual would attain eminence. He quoted her: "...high but not the highest intelligence, combined with the greatest degree of persistence, will achieve greater eminence than the highest degree of intelligence with somewhat less persistence" (p. 362). Simonton considered this motivational aspect a *sine qua non* of successful talent development. Enduring motivation and perseverance would be needed for a talented individual to commit his time and energy to arduous training and practice. He must be prepared to test the limits of his capacity, and risk leaving his comfort zone (Csikszentmihalyi et al, 1993).

Further evidence that intellectual aptitude might be less important than intrapersonal factors was cited in Feldman's (1991) study of six young prodigies. One of the science teachers of a science prodigy (who had been identified by Stanley [founder of the Study of Mathematically Precocious Youth Program] as a Nobel Prize potential) astutely observed that this prodigy in her class lacked a quality of 'curiosity or scientific intuition' that she had seen in her students who had become top-notch scientists. The teacher added that these students were not those who did the best in the science class, but that they had "a difficult to define sense of what was an interesting problem, and always seemed to be able to get to the heart of it" (p.243). Could she be describing what Brandwein termed *questing*? Or could *questing* be a pre-requisite for this 'scientific intuition'?

To Heller (1993), non-aptitude traits such as curiosity and the thirst for knowledge, the need to seek information, persistence and intrinsic motivation generate differences between individuals who exhibit exceptional scientific performance and those who do not. According to Walberg, Williams & Zeiser (2003), research on eminent women showed that although 50% of them showed high intelligence in their early years, 70% of them were not particularly successful academically. Whalen's (1998) report of the study of talented teenagers showed that in talent-related activities, for instance, math and science classes for teenagers with special aptitudes in these areas, *flow* was a more powerful predictor of achievement outcomes (like number of advanced courses, and higher grades in these courses) than academic ability (PSAT scores) or achievement motivation. Adolescents who experienced *flow* in their talent area were more likely to commit to further talent development by pursuing the identified talent further in college. Enrico Fermi, who had six graduate students of his become Nobel laureates, actively sought young student co-workers, and his condition was they had to be *seriously interested in physics,* and of *reasonable ability* (Zuckerman, 1992, p. 160).

Summary

To summarize this section, research suggests that beyond a certain level of intelligence (giftedness) it is the intrapersonal attributes of individuals that are likely to determine if the talented individual would produce world class performance. These factors include love and passion for, and commitment to the talent field; enduring motivation and perseverance to overcome obstacles on the path to achievement, and ascetic dedication to the cultivation of one's talent. However, this does not negate the fact that talent/aptitude has to be present in the first place, an idea which is challenged by Howe, Davidson & Sloboda (1998), who argue that exceptional performance is attributable less to individual differences (level of aptitude) than quality of instruction, practice strategy, amount of time spent on practice, and degree of enthusiasm. Feldman and Katzir (1998) counter-argued that the fact that practice and other factors are important for developing expertise does not rule out the importance of talent. Freeman (1998) too feels that without talent, dedicated effort by itself cannot lead to world class accomplishment, and similarly, Detterman, Gabriel & Ruthsatz (1998) assert that deliberate practice, while important to exceptional performance, cannot equalize outcome. Giftedness/aptitude is a necessary but insufficient condition to produce exceptional performance. Intrapersonal characteristics are what distinguish between those who fulfill their potential or grow up into mediocre adults. Of the highly gifted in Terman's studies who grew up to be underachievers as adults, Simonton (2000) observed: "[h]owever impressive their IQ, some critical factor was missing from their **personal makeup**" (p.114, emphasis added).

External catalysts: Role of the families

In the literature, there is the greatest consensus among researchers about the important role of the family in the talent development process. Most of the high IQ children in the Terman study had high quality home environments (Simonton, 1999). Such homes tend to be exceptionally child-centered (Feldman, 1991) and learning-centered (VanTassel-Baska, 1989a). Moon, Jurich and Feldhusen (1998) cited research that families with high achieving and high IQ children tended to be child-centered and to have supportive family relationships. These families set high expectations for achievement and are vigilant about checking homework, whereas parents of highly creative children tended to encourage independence. Families are not only the launching pads for the child's talent development (Albert, 1995); they also sustain the initial force of discovering the child's talent. Feldman's (1991) study of prodigies revealed that it was the parents who were responsible for the child's first exposure to the talent domain, and by approaching learning with joy and spontaneity, provided the child with opportunities to explore and fall in love with the field. They responded to the child's first manifestations of high interest and ability in that domain by encouraging his progress, and making available the resources to support him. The home abounds with intellectually simulating materials, and children are exposed to a wide array of parents' intellectual interests and thus acquire the hobby of 'omnivorous reading' (Simonton, 1988, p. 111). Parents sought appropriate teachers, coaches, schools, facilities, programs for the child. In some instances, a parent might even quit his job to support the child's talent development.

Although the parents are not able to teach the child beyond a certain level, they help the child maintain a life of balance, as well as clearly spell out expectations of conduct. They protect the child by helping him maintain as normal a life as possible (Feldman, 1991), but they also model the necessary qualities to inspire the child to persist in developing his talent. Parents espouse values essential to talent development. They promote curiosity, risk-taking, experimentation and love of learning (Ciskszentmihalyi et al., 1993), independence of thought (Albert, 1995) and allow the child to experience and cope with the stress and challenges of living up to high expectations and one's potential (Olszewski-Kubilius, 2001). Families of talented teens have been found to place a high value on education and on the need for the opportunity to learn, and display a strong sense of self reliance and assertiveness (VanTassel-Baska, 1989b). Ciskszentmihalyi et al. (1993) suggested that a balance between support and tension in the family was conducive for talent development. They cited studies to show that in homes where "autonomy and attachment and connection with parents were highly valued" (p.154) conditions for talent development were optimal. They argued that families that were complex were the best stimulus for teens' development, and complex families were defined as those that were both integrated and differentiated. In an integrated family, there would be trust and stability, thus freeing the child to feel safe and secure to explore the talent field that he enjoyed. A differentiated family on the other hand would provide challenges, encourage independence and self discipline. A child who grew up in a family that was integrated and differentiated would be more likely to experience *flow* in the home. Ciskszentmihalyi et al.'s (1993) study of talented teenagers showed that integration and differentiation made unique contributions, with "the former accounting more for the youth's buoyant moods and energy, and the latter for positive evaluations of future expectations and goals" (p.164). They also found that complex families were very efficient in the pattern of time use, and teens from such homes were more engaged in more and better 'quality' productive activities, and performed them with more intensity and enjoyment. While acknowledging that many eminent people grew up in tumultuous families, Ciskszentmihalyi et al. reiterated that complex families were not a necessary ingredient for the achievement of eminence, but they did suggest that such families increased teenagers' chances of staying the course, and refining their talents.

Monsaas and Engelhard (1992) used data from the Bloom study (1985) to determine the family's impact on the talented individual's level of competitiveness, and found that home environment accounted for 46% of the variance in individual competitiveness. They found that the correlation between home environment and individual competitiveness for research mathematicians was highest among the four domains studied (tennis players, swimmers, pianists) and concluded that in talent domains that do not foster competition, the home environment has a stronger impact on the individual's competitive attitudes and behaviors.

Milgram and Hong's (1999) study of family influences on the realization of scientific giftedness in highly gifted Israeli adolescents found that in general, adolescents whose giftedness was recognized perceived their family dynamics very positively. Respondents described their families as highly coherent, reported that assertiveness and self-sufficiency were encouraged and achievement was prized.

Summary

To conclude this section, it appears that families, including dysfunctional ones, have a significant impact on a talented teen's development in the talent field. As is true of other factors, *how* families impact the teenager differs from individual to individual. But one point is probably true of all families, and Feldman (1991) best sums it up thus: "[Parents] can respond to their [children's] indication of interest and ability, encouraging and facilitating their progress. But they should not force-feed or push their children into activities. The primary impetus must come from the children themselves. They, and not their parents, must possess the motivation and drive to pursue excellence" (p.120). To Gardner (1997), "...while prodigiousness begins with individual talent, it cannot come to fruition without a good deal of support...No one, no matter how talented, can forge ahead alone" (p.46). This support could come from the parents or significant others like a mentor.

External catalyst: Role of special programs like mentorships

Gifted students are deemed to be particularly suited for mentorship experiences because of their ability to work independently and their high degree of motivation (Clasen & Clasen, 2003; Ellington, Haeger & Feldhusen, 1986). Mentorships allow gifted students opportunities to focus intensely on their area of talent and interest and explore it in a 'ceilingless' environment (Purcell, Renzulli, McCoach & Spottiswoode, 2002), because a good mentor establishes an environment in which the student's accomplishment is limited only by the extent of his talent (Committee of Science, Engineering and Public Policy, [COSEPUP],1997). Sternberg and Davidson (1985) had noted that among the factors that enhance the talent development process, "there must be outstanding instruction and mentorship in the field. Prodigies have typically been exposed to the very best mentors in the field and placed on a regimen that enabled them to exploit their gifts maximally" (p. 56). A decade later, Glass (1996) wrote of the Talent Search: "[E]ven the strongest [high schools] do not have the resources in terms of personnel or laboratories to mentor this level of scientific research" (p.165). A headline in the *New York Times* dated March 9, 2005 echoed the same theme: "High school students cannot do research at this level [Intel Science Talent Search Finals] without mentors" (Winerip, 2005)

How do mentorships help to advance talent development in gifted youth? Research has shown that effective mentors exert a powerful and lasting influence on their mentees. In a study of Presidential scholars, Kaufman (1981) found that respondents benefited from mentors who set an example, offered intellectual stimulation, shared their joys and excitement of their work, and understood their needs. Indeed according to the collective wisdom of award-winning mentors, the mechanics of mentorship boils down to these: Mentors serve as a role model and let the mentee watch him perform difficult tasks, see him fumble, and handle difficulties.

Mentors provide opportunities for mentees to conduct research – give them space to practice and make mistakes, check in on their progress and listen to their frustrations and success (Adams, 2004). Mentors allowing the mentee a glimpse of the lifestyle associated with their profession sometimes helps to "unlock the future". Little wonder that parents think mentors have a maturing effect as their children after a mentorship "suddenly develop a vision of what they can become, and find a sense of direction" (Berger, 1990). Good mentors share life experience, wisdom and expertise. They impart knowledge and skills to provide guidance towards the life to follow (Casey & Shore, 2000). Mentors are also conduits for value systems that are part of the tradition of the field (Pleiss & Feldhusen, 1995). They show by example what is meant by ethical conduct, and expose mentees to the notion of scientific integrity so that they will be better prepared to deal with ethical issues in their own work (COSEPUP, 1997). According to Pleiss and Feldhusen (1995), research on people who had been mentored found that "the real significance of the relationship to gifted adults is the transmission of attitudes and values" (p. 160).

Mentorship programs can benefit both the mentor and mentee. An experienced mentor of Intel Talent Search finalists offered: "...the nice thing about working with high school students is that they are willing to try out theories that are 'a little crazy' but need to be tested. Graduate students are often less willing to take the risk because of the concern of getting a degree and making a living" (Winerip, 2005). This professor's sentiments are shared by a mentor in the SRP: "It is the group of students who is actually pushing the frontier of science which had made me most proud and satisfied." (MOE, 1997). Another SRP mentor thought the process of engaging in research was important even if the result was not 'earth shattering'. He said: "If a student is sufficiently motivated, and eager to find out for herself what research is all about, she will realize the excitement of discovery far outweighs the frustrations and uncertainty that inevitably accompanies any such activity. The reward had been in the journey, the quest for knowledge" (MOE, 1997). Schatz (1999) added that many mentors become rejuvenated in their careers when they share it with their students, and are sometimes introduced to new perspectives. In their study of participants in a high school science mentorship program, Davalos and Haensley (1997) reported that mentees perceived benefits in the academic, personal and career areas. In Templin's (1999) study of students in a science mentorship program for high achieving students, mentees reported benefits such as a chance to do real research, learning about themselves and a more integrated understanding of science.

Although mentorship programs are suitable for gifted students in general, not any good student is a candidate for a mentorship. Similarly, not every professional or expert is suitable to be a mentor. Almost any study on mentorships would stress the importance of ensuring that mentors have sufficient time and interest to be real role models, that they will understand and accept the student's abilities, needs, interests and expectations. At the same time, students who wish to be mentored should be prepared and told about the responsibilities, commitment and expectations associated with the mentorship. Not only the benefits but the limitations of the mentorship ought to be made explicit. For instance, students need to understand the professional pressures and time constraints mentors face, the multiple demands on the mentors' time as mentoring is never the primary responsibility of faculty. Mentors, on the other hand, can ensure quality time by establishing 'protected time' – minimizing interruptions by phone calls or visitors when meeting with a mentee (COSEPUP, 1997).

The long term impact of mentors should not be underestimated. In her study of people who leave science, Preston (2004) found that "the positive guidance of a strong mentor was a primary difference between women who stayed and those who leave" (p. 98). Many women interviewed felt that positive mentors advanced their careers or that indifferent mentors impeded their careers. Preston felt that mentoring had a crucial impact on the persistence of women in science. She also found that men were less affected by their mentors, although many men who remained in science felt that the mentoring process had positive long term impacts on their success in the field.

Attrition from Science

Preston's (2004) findings about the differential impact of mentoring experiences on men and women's decision to leave science are not unexpected. Research shows that men and women who major in math and science courses do not necessarily end up with careers in science (Subotnik & Steiner, 1995; Subotnik, Stone & Steiner, 2001) In fact, evidence suggests that a considerable number of them leave the science pipeline. Among the reasons cited for the switch out of science are lack of a supportive mentor, choice of wrong course (in high school and college), disillusionment with science careers, and a new-found interest in other (non-science) careers and activities. Some research on younger gifted students suggests that students' interest in science starts to decline by the middle and high school years (Farenga & Joyce, 1998), and that the situation is worse for girls than it is for boys.

Brandwein (1995) has suggested that the premise that curriculum and instruction for the science talented should aim at the apex – the research scientist – requires reexamination (p.xiii). He contends that skilled artisans and technicians also make valuable contributions in competent research laboratories. The research base on attrition from science, however, is not focused at the artisan and technician level. Researchers on this issue seek to find out what it is about *science* that makes individuals who have talents and interest in the field quit. Or does the answer lie in the *individuals* themselves? Does it take a certain personality type to persist in science?

Longitudinal studies have shown that students who major in science (including mathematics, engineering and technology) in college do not always stay the course. In fact, in a report by the National Science Board ([NSB] August, 2003), it was pointed out that surveys of freshmen show high levels of interest in science and engineering, with about 25 to 30% intending to major in these programs. However, the net movement of undergraduates tends to be **out** of these fields into other majors or out of college (p. 18). As a result, more than 50% of those who intend to major in science and engineering fields drop out of these majors. At more advanced levels, there is even more widespread concern about the declining enrollment of American citizens and permanent residents in science and engineering doctoral programs (NSB, 2003).

In a longitudinal study of 1983 Westinghouse Talent Search semifinalists and finalists, Subotnik and Steiner (1995) found in the first wave of data collection, that 97% of their 146 respondents had planned careers in research or applied science or mathematics. By the second data collection point four years later, of the 94 who responded, 22 of them had left science, and of these 22, 15 were women. Those who remained in science were more likely than those who had left the field to have had enthusiastic science professors who encouraged them in their endeavors. All but one were able to identify an individual who had mentored them. By contrast, those who left science did not have adequate role models to support them. Two years later in 1990, when the cohort was surveyed again, 11 of the 60 (18.3%) men and 13 of the 38 (34.2%) women had left the field. The reasons the men gave for leaving science were poor quality of instruction, high interest in courses outside science, unappealing lifestyle of scientists, and the realization that the initial choice of science had been the parents' or school's, not their own (Subotnik & Steiner, 1992, 1995). Three of these men felt that their high school coursework had not prepared them adequately for the rigorous program at the college level; interestingly only 13 of the 49 who stayed in science felt adequately prepared by the high school they attended.

The women who left the field gave more diverse reasons. The role of the mentors seemed more important to the women. Five of the 13 could not identify a mentor, while seven had mentors outside of science. Of the 13 who left, seven said they could have remained in science if classes had not been so impersonal, and circumstances had not impeded their progress.

Subotnik, Stone & Steiner (2001) did a fourth round of interviews with the subjects when they were 34 years old. Of the eighty five of the 1983 cohort who responded, 11 of 52 men (21.1%) were no longer involved professionally in science, while 13 of 33 women (39.3%) had left the field. The reasons for leaving science included disillusionment with the lifestyle of scientists, insufficient support from the institution and the fact that other domains of study were more interesting. For the women who remained in science, few talked about sexism or constraints on career development; instead they talked about career choices that interfered with lifestyle values.

Tobin and Fox (1980), however, had found that gifted girls of similar ability to gifted boys tended to gravitate towards careers of a social or artistic nature. They attributed this to a difference in values between boys and girls, as measured on the *Allport-Lindzey Study of Values*. While boys scored higher on theoretical values and had a well-developed interest consistent with academic pursuits in mathematics and science, girls scored higher on social values, which appeared to be in conflict with their mathematical potential (p.181). Eccles (1985) also reported clear differences in the interests and values of gifted males and females. Those held by females were likely to be social and aesthetic as opposed to scientific. This finding was confirmed by Olszewski-Kubilius & Kulieke (1989) who studied a group of gifted adolescents who participated in a Midwest Talent Search (MTS) summer program. Lubinski and Benbow's (1995) Study of Mathematically Precocious Youth also found that gifted females were relatively equally committed to career tracks involving aesthetic forms and social and theoretical domains, compared to gifted males who were expected to gravitate toward the theoretical math/science pipeline. Their longitudinal studies of several cohorts of SMPY participants consistently found more males than females in mathematics, engineering and physical science courses (p.271). Siegle and Reis (1998) attributed this to teacher (mis)perceptions that girls' quality work was the result of hard work, and tended to see boys as being better at math and enjoying it more, and girls seem to accept their teachers' evaluations. The attitudes of teachers and counselors have been found to have more influence on girls than on boys in terms of coursework and career expectations of girls (Le Maistre & Kanevsky, 1997). Kerr and Nicpon (2003) went further and asserted that "one mediocre grade in a beginning course may discourage gifted women from persisting, probably because of the tendency of females to attribute this 'failure' to lack of ability" (p. 501).

Arnold (1992) found in her study of valedictorian women that attrition from science began early in the women's college career. However, these women's departure from science was not due to academic or job failures. Instead, their career choice was shaped by their future role as parents. Even those who were in science careers (e.g. physicians, or chemists) anticipated reducing their labor force participation to raise their children. Unlike Subotnik & Steiner (2001), Arnold concluded that gifted women's achievements were influenced by their values and life role expectations, and that women would continue to grapple with the career-family conflict. Her conclusion is echoed by Fleming & Hollinger (1995) and Silverman (1989). This discussion of attrition in science invariably leads to another troubling issue – that of the lack of representation of women in the field.

The gender equation in science

The *New York Times* reported a recent survey which examined the top 50 departments in many science and engineering fields, as ranked by the National Science Foundation, from 2000 to 2002, revealed that although more women are earning doctorates in science and engineering, women remain scarce in tenured, or tenure-track positions (Lewin, 2004). White men still dominate university professorships at the nation's top science and engineering schools, even where many of the doctoral students are women and minorities. Women hold between 3 percent and 15 percent of full professorships in science and engineering at the schools surveyed. As a result, women can earn their degrees without having a woman professor or even having access to a female faculty member, according to the survey. "Women are less likely to go into and remain in science and engineering when they lack mentors and role models," the survey said. "When female professors are not hired, treated fairly and retained, female students perceive that they will be treated similarly." In some instances, the percentage of female students far outweighs the proportion of professors of the same gender, the survey showed. For example, 48.2 percent of students earning bachelor's degrees in math were female, but only 8.3 percent of math professors were women (Latzke, 2004). "Despite 30 years of effort to close the gender gap, it hasn't happened. In 1973, for example, roughly 3 percent of tenured professors among the nation's scientists and engineers were women; by 1995, women still only accounted for less than 10 percent of full professorships in these fields" (Cromie, 1999). Rossiter's (2004) study on the science glass ceiling revealed an inverse relationship between faculty rank and percentage of women, and the women scientists shared their struggle to succeed in the hostile, competitive world of science. As Nancy Lane, a professor of Science at Cambridge University pointed out: "...it was no longer possible to assume that an absence of women in science was due to women themselves, rather than the institutions to which they belonged" (Lane, 1999). A paradigm shift needs to be made away from asking what is wrong with women to questioning what it is about the environment of the fields of science that it does not attract and retain the interest of girls and women. "I don't think there's conscious discrimination," said Howard Georgi, a professor of physics at Harvard. "However, it's clear something about the way we do things amounts to unconscious discrimination" (Cromie, 1999).

Pre-college science taking

The problem of the 'missing females' can probably be traced to gender-related attitudes towards mathematics and science in elementary school students. While Farenga and Joyce (1998) suggest that interest in mathematics and science starts to decline by the middle and high school years, Swiatek and Lupkowski-Shoplik (2000) found that attitude differences in gifted students exist as early as elementary school. Boys tend to favor science and technology while girls prefer English, writing, reading and foreign language. They also suggest that girls' negative attitude towards science and technology increased from third through sixth grades. Zorman (1996) also found research reporting such a trend. In a 15-year study of sex differences in Israel, Friedler and Tamir (1990) found that from the ninth grade onwards, males expressed a significantly more positive attitude towards the sciences than females. Given this trend, is it any wonder then that studies on gender-related differences in participation in challenging courses and examinations should find unequal numbers of male and female students for several subject areas, especially those in the sciences and mathematics?

According to Stumpf and Stanley (1996), in 1985 about 85% of students taking the Advanced Placement (AP) Physics C (Electricity and Magnetism) examination were male. The same was true for the 1985 Computer Science examination. Ten years later, the ratio for Computer Science remained at 6.75: 1, in favor of boys, a discrepancy the researchers find 'disquieting', given the "constantly growing significance of computer science on everyday life" (pp.362). Reis and Park (2001) cited a study by Gavin (1997) in which only 27% of high-mathematics-ability seniors expressed interest in mathematics or science major. For females, only 0.7% selected computer science, 3.3% engineering, 1.4% mathematics and 2% physical science.

Since there are so few girls in advanced mathematics and science courses, researchers like Stanley had expected that the few girls would be high-achieving. However, he and Stumpf (1996) found great gender-related discrepancies in the test scores of the College Board Advanced Placement and Achievement tests. They found that in AP examinations from 1984 to 1992, male students had an advantage over female students, corresponding to a *d* of at least .20 in 10 of the 24 subject areas studied. Listed are the math and science courses, in decreasing order of the effect-size estimate, Computer Science (.59), Physics (mechanics), Physics (electricity and magnetism), Chemistry, Biology, and Mathematics (Calculus BC) (.20). In all these areas, the percentages of male students at the upper tail of the score distribution were greater than those of female students. In Computer Science and the three Physics examinations, the percentages of male students at the upper tail were more than *twice as large* as the percentages of female students. In the 1982 Achievement tests in Physics, Mathematics I, Chemistry, and Biology, too, the percentage of male students attaining the highest scores (700-800) was more than twice as large as that of female students.

This gender imbalance exists in the Scholastic Aptitude Tests (SAT) too. In 1996, the population of girls taking the SAT averaged 46 points less than boys on the math section of the test. As for those who scored more than 700, 8% were boys and 3% were girls. (Reis and Park, 2001). The size of the gender gap on the math section of the SAT has remained constant since 1972 (College Board Online, cited in Hyde and Kling, 2001).

The question that continues to puzzle researchers is what accounts for the gender gap in enrolment and performance? A number of possibilities have been forwarded. Le Maistre and Kanevsky (1997) conjectured that if parents stereotyped mathematics as a male activity, their gifted daughters' later mathematics success and interest would be adversely affected. Eccles and Harold's (1992) studies of gifted girls revealed that although girls' confidence in their math ability equaled that of the gifted boys, the girls had *more* confidence in their reading ability. Girls' confidence could also have been undermined by all the publicity about the gender gap in performance in high-stakes tests like the AP and the SAT (Hyde and Kling, 2001).

As for the factors contributing to boys' stronger performance, Hyde and Kling (2001) attributed it to the fact that there is greater variance in the scores of the males (although they readily admit they are not able to account for the greater variance) resulting in their overrepresentation in the upper 5% of the distribution. Stumpf and Stanley (1996) thought it might be possible that the male-dominated classroom could lead to a chillier class climate, resulting in females learning the material less well. Csikszentmihalyi & Schneider (2000) found that the courses a student studied in high school seemed to be directly related to the type of college he or she attends. Taking advanced level math and science courses increased the odds that a student would attend a more selective college. Students who took math and science courses at advanced or honors levels were more likely to attend more competitive universities, whereas students who took a minimum number of these are rarely admitted to them. (p. 232). This finding was also reported among high school students in Israel where the special status of mathematics and the sciences make them relevant and useful (perceived as such) for all students who wish to enroll in college (Ayalon, 2003). She reported that applicants to the selective but not mathematically-oriented fields of law and medicine took many units of study in mathematics, and concluded that "taking advanced science courses in high school reflects students' ambition and motivation, and not necessarily their interest in the subject matter" (p. 7). Many of those who leave science were girls; could girls' lack of interest be a contributory cause of their weaker performance vis-a-vis the boys?

Last but not least is Hyde and Kling's (2001) explanation of the impact of the stereotype threat on girls' performance. Hyde and Kling reported a series of studies in which researchers varied the instructions given to undergraduates working on a set of mathematics problems from the Graduate Record Examination. When instruction included information that gender differences were expected, the information was interpreted to mean that males would do better, and the males in the sample did do better than the females. However, when instructions indicated that the test had not been known to yield gender differences, men and women performed equally well. Hyde and Kling believed that the removal of the stereotype threat had lowered the anxiety level of the women and enabled them to earn a higher score that reflected their true ability. In the control group, where no mention was made of gender differences, the men did better. Hyde and Kling found the control group situation similar to the testing situation students face in the SAT. Given the wide publicity of the gender-gap on the math portion of the SAT, males **and** females alike believed males would perform better. The stereotype threat has thus depressed female test-takers' scores. Inzlicht and Ben-Zeev's (2003) experiment on threatening environments demonstrated that "merely placing high-ability women in a room where men outnumber them creates a threatening intellectual environment, and consequently leads them to do worse on a math test" (p.803).

To sum up, it appears that there are a myriad of factors to account for the gender imbalance in the math/science pipeline. How much of it is due to factors that are 'malleable', and how much of it is due to innate differences between the two sexes? How far should policy makers 'intervene'? In the context of the study to be undertaken, do these research findings done on western populations in western societies hold true for a non-western society?

Summary

To set the backdrop for the study of the SRP, various conceptions and models of talent development were reviewed. While emphasis was placed on research studies that are consonant with Gagne's model of talent development, differing views about the relative importance of intrapersonal and external catalysts were discussed. The special role of teachers and the school, parents and the home as well as special programs and the role of mentors were shown to be crucial to talent development. Literature on issues germane to the domain of science was also reviewed – what kinds of programs lend themselves to the identification of science-prone students? Why is there a gender imbalance in advanced science classes in school and at college? Why do females shun science careers or are there factors at work that keep them out of the field? Table 1 summarizes the review of literature by theme. Research findings on these questions have provided a basis for comparing the findings of the study to be undertaken. The next chapter outlines the methodology employed in this study.

Table 1: *Summary of Literature reviewed by Theme*

I. Effects of *environmental* factors on talent development in the sciences

Key external influences	Relevant studies	Findings
Role of teachers	Bloom (1985); Brainard & Carlin (2001); Casserly (1974); Csikszentmihalyi, Rathunde & Whalen (1993); Csikszentmihalyi (1996); Gardner (1997); Seymour & Hewitt (1997); Subotnik & Stenier (1995, 2001); Whalen (1998); Zuckerman (1992)	• Different roles at different stages • Role model passion for teaching, and for the subject • Guide students, and yet allow them freedom to explore, to do independent work
Role of parents/home	Albert (1993); Bloom (1985); Feldman (1991); Csikszentmihalyi et al (1993); Monsaas & Engelhard (1992); Milgram & Hong (1999);Olszewski-Kubilius (2001); Simonton (1998); VanTassel-Baska (1989a; 1998)	• Child-centered and learning-centered • Provide appropriate resources • Children are happiest in complex families and least happy in differentiated families
Role of programs/schools	Benbow & Lubinski (1993; 1995); Brandwein (1995); Bloom (1985); Gross (2004); Pleiss & Feldhusen (1995); Gustin (1985); Sosniak (1985); Stanley (1993); Subotnik & Stenier (1995); VanTassel-Baska (1992,2001)	• Course work in high school not rigorous enough – cannot cope with course work in college • Acceleration and other advance programs increased individual's confidence in own ability • Inspiring learning and teaching would enable students to discover if they are science prone

II. Effects of *intrapersonal* factors on talent development in the sciences

Key internal characteristics	**Relevant studies**	**Findings**
Industriousness, hard work	Bloom (1985); Csikszentmihalyi, Rathunde, & Whalen (1993); Feldman (1991); Howe (1993); Roe (1953); Sosniak (1985; 2003)	• Capacity to work long hours • Capacity to work hard • Practice, practice, practice
Motivation/Passion	Bloom (1985); Csikszentmihalyi (1996); Csikszentmihalyi, Rathunde, & Whalen (1993); Gruber (1998); Heller (1993); Piechowski (1999); Simonton (2003); Whalen (1998)	• Absorption in the work • Love for the work – feeling for the organism (B. McClintock) • Joy of solving problems
Persistence/Commitment	Cox (1926; 1992); Feldman (1991); Gardner (1997); Heller (1993); McGrayne (1992); Simonton (2003, 2004) VanTassel-Baska (1989b)	• Persevere in face of setbacks • Sense of mission to make contribution • Single-minded focus on task
Curiosity	Bloom (1985); Brandwein (1995); Cox (1926, 1992), Csikszentmihalyi (1992); Heller (1993); Simonton (2004)	• Always asking questions • Not easily satisfied with explanation of phenomena • Open to experience and ideas

III. Gender issues in math & science

Key issue	Relevant studies	Findings
Biological differences	Stanley (1993); Benbow & Lubinski (1993; 1995); Freeman (2004)	• Boys do better than girls in quantitative sections of SAT even though test items do not have gender bias • Differences appear as early as Grade 5 • No such differences in achievement tests (in UK)
Differences in values-orientation	Arnold (1992); Benbow & Lubinksi (1995); Colangelo & Kerr (1990); Eccles (1985); Flemming & Hollinger (1995); Jacobs & Weisz (1994); Olszewski-Kubilius & Kulieke (1989); Reis (2003); Stanley (1993); Tobin & Fox (1980)	• Boys oriented toward theoretical, political and economic; girls oriented toward aesthetic, social and religious • Girls have wider career choices because of values orientation and are less likely to work in math/science fields that are more theoretical • Girls in math field found to have higher theoretical orientation than males in non science field
Environmental milieu (supportive/hostile)	Brainard & Carlin (2001); Eccles (1985); Hyde & Kling (2001); Preston (2004); Rossiter (2004); Siegle & Reis (1998); Subotnik & Steiner (1992, 1995); Subotnik, Steiner & Stone, 2001).	• Girls' perceived weakness in math • Freshmen felt ignored by universities • Support of mentors and peers • Unappealing lifestyle of scientist
Females' role in the home	Arnold (1992); Arnold, Noble, & Subotnik (1996); Kerr (1997); Silverman (1989)	• Career decisions took into consideration plans for marriage and family • Women pursuing higher degrees opt out of marriage • Men expect continuous fulltime labor participation; women's career disrupted when they have children

Chapter 3

Methodology

This chapter outlines the major approaches that were employed in the study. It includes a brief description of the Science Research Program, the sample, instrumentation, measures taken to enhance the rate of returns and ends with a discussion of the limitations and delimitations inherent in the research design.

Purpose of study

The purpose of this study was to explore the talent development process of gifted science students in Singapore. It sought to isolate the factors that contributed to their interest in science, and to find out if gifted science students who gravitated towards science in adolescence continue to enroll in science courses in university, and subsequently pursue careers in the field of science. A related purpose of the study was to assess the effectiveness of the Science Research Program in retaining gifted science students in the science pipeline, and helping them to contribute to the field of scientific research.

Brief history of the Science Research Program

In 1987, then Minister for Education, Dr Tony Tan, first mooted the idea of a science enrichment program for first-year junior college (grade 11) students. He felt it was important to give bright students an early exposure to the methodology and techniques of scientific research, and to provide students with the opportunity to work with mathematicians and research scientists to pique student interest in research. To be sure, a small number of outstanding students had been participating in overseas programs like the Center for Excellence in Education summer program at the Massachusetts

Institute of Technology, and the Bessie Lawrence Summer Science Institute Program in Israel. However, participation in these programs was by invitation, and the expenses involved meant that only a few students could benefit from them. Dr Tony Tan wanted to have a local program so that more students could benefit. (MOE, 1997).

The President of the Center for Excellence, Mrs J P DiGennaro was invited to conduct a feasibility study. Meanwhile, teams of officials from the Ministry of Education visited premier high schools in the United States of America to learn more about enrichment programs for high ability science students, while professors from the National University of Singapore (NUS) visited research institutions and held discussions about science outreach programs with university mentors.

In 1988, the Science Enrichment Program was formally launched with a pioneer group of 38 junior college students as a collaborative effort between the faculty of Science, NUS and the Gifted Education Branch, MOE. The following year, the program was renamed the Science Research Program (SRP) to reflect the program's central purpose of promoting science research. The program has since grown from strength to strength and now caters to about 80 students each year.

There are two parts to the SRP. Applicants whose research proposals are accepted are placed under the mentorship of professors and researchers from NUS and other research agencies. Students work in a real-world research environment, and meet with their mentors once a week during school term. During the June holidays, students spend at least two weeks on site working full-time on their research project. Thereafter, the student meets with the mentor on a regular basis until the end of September to complete the research work. Every student is expected to write a scientific paper at the end of the attachment. The papers are published as Proceedings of the Research Congress to be held in March the following year, and students present research findings to an audience of peers and experts in the scientific fields.

Sample

The subjects in this study were three cohorts of students who had participated in the SRP. Each cohort comprised about 70 students. The first cohort was the batch of second year Junior College (grade 12) students who were in the SRP in 2003 (age: 18). The second cohort comprised SRP (Y2000) participants who were in their third year in university for the academic year 2004-05 (age: 21). There are two reasons for the choice of this cohort. Male students would have fulfilled their national service obligations and matriculated and would be in the first year of university. The course enrollment for this cohort would provide an indicator of the number of students who opted to continue to major in science, though it would not be clear yet if they would pursue careers in science. The third cohort comprised SRP (Y1991) participants who would already be in the work force (age: 30). This group would shed some light on the number who stayed in the science pipeline; those who decided to switch out of science would have probably done so by this age. This group could also share if changes in the last 15 years in science and technology as well as in other sectors had impacted their career decisions.

Selection criteria for entry into the SRP are very stringent, and applicants undergo a rigorous selection process. Students must have at most an aggregate of six or seven points for the end of Grade 10 examinations (English Language plus four best math/science subjects) to be eligible for the aptitude test. Each year, about 500 to 600 students sit for the aptitude test. The hour-long aptitude test is designed by professors at the NUS. There are 25 forced-option questions in each of the four sections: math, biology, chemistry and physics. Students will decide in advance any *two* sections they wish to attempt, and the number of questions varies from a minimum of 50 to a maximum of 100, depending on the combinations chosen by the students. No technical adequacy data on the test are available, but they are purported to be measuring math/science achievement "out of level, beyond the 'O' Level" (M. Han, personal communication, August 24, 2004).

Only those who score above average on the aptitude tests **and** have participated in science-related activities in secondary school (grades 7 to 10) are short listed, usually about 120 of them. They are then invited to attend two research method modules over a 6-week period. These modules are lectures and workshops conducted by NUS professors, and held one afternoon a week during the school term. Attendance at these research methods modules is seen as indicative of the students' interest in science, persistence, and how strongly their desire is to participate in the SRP.

In the selection round, short-listed applicants would visit the NUS website to access the directory of mentors and their research interests. If they wish, applicants may even initiate contact with the mentor they would like to work with. All 120 will submit research proposals. Of these, about 70 to 80 will be selected. Final selection depends on the quality of the proposal, as judged by the mentor supervising the proposed project. The screening procedures and minor changes for each cohort are summarized in Table 2.

Table 2: Procedures to screen SRP applicants

<table>
<tr><th></th><th>Test scores</th><th>CCA[1]</th><th>Interview[2]</th><th>Teacher rating</th><th>Aptitude test[3]</th></tr>
<tr><td>Before 1996

Cohort 3
N=69
16F & 53M</td><td rowspan="3">6 points or better for EL and best 4 math and science subjects in grade 10 results[4]</td><td rowspan="3">Active participation especially in math and science related activities</td><td>To assess student interests and attitudes</td><td rowspan="2">Science/math teachers provide feedback on students on an observation scale to rate student's learning, social, emotional, work study and production skills</td><td></td></tr>
<tr><td>1996-2002

Cohort 2
N=77
24F &53M</td><td rowspan="2">*Discontinued – time consuming and disadvantages students who are not articulate*</td><td rowspan="2">Replaces the interview. Students must score above average to make it to the selection round.</td></tr>
<tr><td>From 2003

Cohort 1
N=77
19F & 58M</td><td>*Found to be redundant after RMM[5] introduced*</td></tr>
</table>

[1] Co-curricular activities
[2] Committee comprised science professionals from the National University of Singapore (NUS) and Gifted Education Branch.
[3] There are 4 sections in this aptitude test, with 25 questions in math, physics, chemistry and biology. Prior to the test, students opt for the 2 sections they wish to be tested on. Regardless of section, all applicants have 60 minutes to complete it. The number of questions varies from section to section, ranging from 50 to 100. The test is designed by professors in the NUS.
[4] Based on the GCE 'O' Level exams, scores range from 1 to 9, with 1 being the best possible. To score 6 points, it means applicant must get '1' for at least 4 of the subjects and '2' for one of them. The '2' is usually for English Language (EL).
[5] Research Methods Modules – These are structured lectures and workshops conducted by scientists in the National University of Singapore. Sessions are held once a week during the months of April and May. Applicants who complete the modules are warded a certificate of participation and eligible to apply for the mentorship program. This 'self-selection' on the part of students is believed to be a better indicator of student's attitudes than teacher ratings.

Research questions

What are the factors that lead young gifted students to gravitate toward science? Has the SRP been effective in meeting its objective to nurture a group of the most talented, committed and enthusiastic students to contribute to the country in the areas of scientific research and development? This research study seeks to answer the following questions:

Within and across cohort analyses:

1. What factors led to the SRP participants' early interest in science? To what extent do participants perceive these factors as 'internal' (intrapersonal) or 'external' (environmental)? Is there a significant difference in the response between male and female participants?

2. How do the cohorts differ in their perceptions about science and the influences on their talent development in the field? How has the SRP contributed to students' continuing work in science?

3. What types of teachers and mentors do these gifted science students feel have contributed to the development of their interest in high level science? Is there a significant difference in the perceptions of male and female students?

4. What role do intrapersonal factors appear to play in students' perception of doing science?

5. What role do parents play in students' academic development and does this role differ for male and female students?

Within Cohorts 2 & 3 analyses:

6. Do SRP graduates continue to take courses in science at university and pursue careers in science after graduation? If not, what are their reasons for leaving science?

Instrumentation

The instrument used in this study was a researcher-developed questionnaire to probe participants' perceptions of the variables and forces involved in their talent development process. Theoretical and empirical criteria culled from the literature reviewed were used in the development of the questionnaire. A table of specifications showing the research-based constructs probed in the questionnaire may be found in Table 3. Items included forced-choice and open-ended questions. To quantify responses, a 4-point Likert scale was used.

Table 3: Table of specifications for (Y1990) questionnaire (forced-choice items)

Questionnaire Section	Constructs	Research studies supporting construct	Item Nos.	Percentage (within each section)
Part I Demographics	Gender differences Developmental differences Ability differences Achievement/accomplishment differences SES differences	Benbow & Lubinsk (1995); Eccles (1985); Preston (2004); Stanley (1993); Gagne (2003); Simonton Benbow & Lubinksi (1993, 1996) Subotnik & Steiner (1995) Bloom(1985)	Pages 1 &2	N.A.
II(i) Factors that influence science interest (15)	Program/school impact Teachers/role models Home/parents	Brandwein (1992); Stanley (1993) Bloom (1985); Sosniak (2003); Gagne (2003); Czikscentmihalyi et al (2003) Bloom (1985); Czikscentmihalyi et al (1993); Feldman (1991); Milgram & Hong (1998)	4, 5, 6, 7,8 1,2,3 9, 10, 11, 12,13,14,15	33% 20%[6] 45%
II (ii) Personal traits (29)	Curiosity Persistence Passion/motivation Abilities Interests Traits	Heller (1993); Simonton (2004), Roe (1965) Cox (1992); VanTassel-Baska (1989, 1996) Gagne (2003); Simonton (2004) Bloom (1985); Sosniak (2003) Simonton (1998, 2004)	16 a, m, q, u, 16 k,x,y 16 s,t,aa 16 d,h,j,m, 16 b,c,e,f,g,i,p,v,w,z,ac 16 l, o, r, ab	14% 10% 10% 14% 38% 14%
III – Science Research Program-specific questions: Reason for joining (13)	Finding out what is available (curious) Access appropriate resources Influenced by others Extrinsic motivation	Brandwein (1992, 1995) Bloom (1985); Brandwein (1995), Bloom (1985); Subotnik & Steiner (1995) Csikszentmihalyi (1992) Heller (1993)	18,20,28,29 19,26.30 21,22,23,27 24,25	31% 23% 31% 15%
Impact of program and student perceptions of program (22)	Based on objectives of SRP (12) Qualities of mentors (10)	Brandwein (1995); Stanley (1993) Bloom (1985); Subotnik & Steiner (1995)	31 to 42 43a to 43j	55% 45%

[6] Open-ended question allows for qualitative feedback

Table 3(contd.)

Section (no. of items in section)	Constructs	Research studies supporting construct	Item Nos.	Percentage
Part IV: Course-taking and career decisions (29)	Quality of classes	Bloom (1985); Brainard & Colin (2001); Csikszentmihalyi et al (1993);	44,48,56,68	14%
	Influence of others (mentor)	Kaufmann (1981); Subotnik & Steiner (1995)	45,71	7%
	Motivation (intrinsic & extrinsic)	Csikszentmihalyi (1992); Gagne (2003); Piechowski (1999);	47,49,54,57,62,63,64, 70,73,75,76,77	41%[7]
		VanTassel-Baska (1996)	46,52,55,80	14%
		Feldman (1991); Gagne (2003)	53,66,72	10%
	Opportunities	Bloom (1985); Subotnik &		
	Interests	Steiner (1995)	65, 69	7%
	Abilities/temperament	Arnold (1992); Bloom (1985)		
		Gagne (2003); Preston (2004);	78,79	7%
	Quality of environment	Subotnik & Steiner (1995)		
Part V: Role of teachers (15)	Quality of effective teachers including knowledge, passion, skills, openness, caring,	Bloom (1985), Csikszentmihalyi et al (1993),Whalen (1998)	81a to o	100%
Part VI: Personal values & beliefs (12)	Traits:			
	hard work	Bloom (1985); Roe (1965)	86 a,b,d,e	33%
	persistence/commitment	Cox (1992); Heller (1993)	86, c,j	17%
	motivation	Csikszentmihalyi et al (1993); Piechowski (1999), VanTassel-Baska (1989)	86 f,h,k	25%
	interests/preferences	Bloom (1985); Benbow & Lubinksi (1995)	86 g,i,l	25%
Part VII: Parental influence (20)	Expectations	Bloom (1985};	87a,b,d,e,g,j,k,t	40%
	Support	Csikszentmihalyi et al (1995);	87f,h,l,o,p,r,s	35%
	Supervision	Feldman (1991}; Gagne(2003) VanTassel-Baska (1989)	87c,i,m,n,q	25%
Part VIII: Career views (8)	Motivation	Csikszentmihalyi et al (1993);	88a,c,d,g	50%
	Satisfaction	Subotnik & Steiner (1995)	88b,e,f,h	50%

[7] Higher percentage because questions are asked in positive and negative form to probe reasons for staying in or leaving science

The questionnaire was reviewed by a purposive sample of three experts; one was a research coordinator who had done extensive research on the talent development of American academic Olympians; a second was the director of a governor's school for gifted math and science students who had many years of experience and involvement in the identification and education of gifted science students; and the third was a Singaporean education professor specializing in gifted education in that cultural context. The questionnaire was then piloted with a group of 18-year old students in one of Singapore's top junior colleges who were enrolled in advanced math and science courses. The pilot data showed reasonable variability in specific dimensions such as boys' and girls' perceptions of math and science classes and science careers. Gender differences varied, however, depending on the subject content and career fields. There was also variability in the way boys and girls perceived the role of their parents in nurturing their early interest in science.

For this study, the questionnaire was modified based on open-ended feedback from students in the pilot survey as well as two focus group discussions with participants in the pilot sample. This ensured inclusion of questions that would reflect an emic perspective. The modified questionnaire was independently rated by content experts, using a standard rubric to ensure an adequate level of content validity. The overall average agreement among them was a respectable 2.84. (See Appendix A for a copy of the rubric, as well as the average ratings for each of the sections.) A copy of the questionnaire for Cohort 3 may be found in Appendix B.

Tests were run to establish the reliability of the various subsections of the questionnaire. The results are summarized in Table 3. The alpha coefficients for the subsections ranged from .678 to .917.

Table 4

Reliability Table for Subsections of the Questionnaire

Section	No. of items	Cronbach's alpha	Standard Deviation	Mean
Factors contributing to early interest in science	15	.789	5.8	41.87
Factors prompting participation in SRP	13	.678	4.2	34.46
Impact of the SRP	7	.880	4.1	20.56
Impact of mentor	6	.917	2.9	17.89
Impact of parents	20	.871	9.6	58.74
Career Views	8	.846	4.5	21.33

Altogether, 60% of the items focused on external influences while 40% dealt with the internal influences on the students' talent development in the sciences. In addition to the forced-choice items, respondents were requested to express their opinion on a number of issues in the open-ended sections of the survey. These were meant to do with the following:

- To probe their perceptions on the impact of the SRP on their talent development;
- To probe their impressions of memorable math/science teachers who had played a major role in nurturing their interests in science;
- To probe impediments, if any, to their talent development;

- To probe the nature of their involvement in science, and the extent to which the SRP had influenced the course and career decisions of those who remained in science;
- To seek their views on acceleration, a highly recommended intervention which has a strong research base of its effectiveness especially with high ability students in math and science; and
- To ascertain if 'history' – changes and advancements in science and technology in the last 15 years - had in any way impacted the course and career decisions of the three cohorts, and if the older cohorts would have made different decisions on hind sight.

In this study, the three SRP cohorts were surveyed at the same point in time, but they were at different points in their academic and work life. As such, the first section of the survey would be identical for all three cohorts, but the second part probing choice of courses in university and career decisions was differentiated for each cohort. For Cohort 1 (age: 18), they were asked about their *future* course options in university and career plans. For Cohort 2 (age:21), who were currently in university, those who were enrolled in science courses were asked for their views on these classes whilst those who had opted for *other* courses outside science were asked for the reasons. Both groups were asked about their *future* career plans. For instance, did those enrolled in science courses intend to pursue a career in science? For Cohort 3 (age:30), those who did not enroll in science courses were asked for their reasons. Those who were in science courses but were not in science related careers were asked why they chose to leave the field. Those who were in science-related careers but opted to leave for other jobs were asked why they did so. All three groups in Cohort 3 were asked about satisfaction with current careers, and if they had plans for further studies.

For all three cohorts, there were a few open-ended questions for participants to offer their insights. The questionnaire took participants about 45 to 60 minutes to complete.

Procedures for the study

One of the pitfalls of survey research is that the generalizability of findings Depends to a great extent on the rate of response from respondents who control the data collection process (Gall, Gall & Borg, 2003). Fortunately for researchers, there are measures that can be taken to ensure a higher response rate. For the purpose of this study, the following measures were taken.

A meeting was held with the Chairman of the SRP Committee who is also Vice Dean of the Faculty of Science, NUS to explain the rationale for the study, and to secure his support. He gave his endorsement, and agreed to write a letter to SRP graduates to encourage them to participate in the survey. A copy of the letter is in Appendix C.

The questionnaire was administered to the 18 year-olds through their teachers, who were requested to collect all surveys and return them to the Ministry of Education. These were later couriered to the researcher in the USA. Asking the teachers to collect surveys ensured a higher rate of return. The 21 year-old and 30 year-old subjects had been pre-contacted during the summer. The purpose was to check if their given street address was still valid, and also to ask for their email addresses. In many cases, it was the parents or sibling who answered the calls. The researcher explained the purpose of the call and managed to update the current contact details for more than 60% of each cohort.

For subjects whose contact details were out-dated, an effort was made to contact them through their friends whom the researcher managed to contact, or through teachers who had taught them and were still in touch with them. Emails were sent to the subjects to seek their consent to email the surveys to them. The SRP chairman who is also a key member in the NUS Alumni also tapped the database of the NUS to trace those who had graduated or were enrolled in NUS.

Apart from those who had specifically expressed the wish to receive the survey via email, other participants received a paper survey. They were given a pre-paid self-addressed envelope to return the surveys to the Ministry of Education. They were also given the option to go to the SRP website to download a copy of the form to email it back to the researcher if that was their preference. For those subjects whom the researcher failed to reach, (because phone numbers were no longer valid), a copy of the questionnaire was sent to the (old) address in the database.

Finally, respondents were informed on the cover page of the questionnaire that for every questionnaire returned to the researcher, two Singapore dollars would be pledged to the Singapore Children Cancer Foundation.

Schedule

To avoid administering the survey during the end-of-year festive period when people would be away on vacation, it was decided to administer the survey before mid-November. In fact, Cohort 1 students were taking the Cambridge General Certificate-in-Education 'Advanced' Level Examination from the first week of November to early

December. Starting earlier would also mean ample time for the researcher to send the survey a second time before the male students in Cohort 1 enlisted for National Service the week immediately after their examination. For these reasons, the time schedule for the data collection was as follows:

Time schedule

October 04	Applied for IRB
End October 04	Administered questionnaire to 18 year-olds through the SRP teacher in each junior college Sent surveys by conventional and electronic mail to Cohorts 2 and 3
End November to 2nd week of December	First wave of surveys expected; reminders sent to those who have not returned them. ('A' Level exam ends 1st week December) Posted a copy of the questionnaire on the SRP website when the letter from the Chairman was finally ready
2nd week December	Deadline for return of surveys (for Cohort 1 students did not return them through their teachers)
End December	Deadline for return of surveys for Cohorts 2 and 3
1st week January 05	Sent an email to inquire about non-respondents, and followed up with a third questionnaire
End January 05	Final deadline for all non respondents to return surveys
February 05	Began data analysis

The researcher encountered a few problems in the implementation of the schedule. Contrary to expectations, not all the Cohort 1 students could be reached. By the time the survey was administered, a few of the junior colleges no longer required students to attend school as students preferred to stay at home to prepare for the 'A' Level examinations. As such, students had to be reminded after the end of their exam to return the surveys. Some of them claimed to have lost the questionnaire, and promised to complete and return it if another copy could be emailed to them. Not all of them kept their promise, hence accounting for the less than 100% return rate.

Contacting Cohort 2 students posed a different kind of challenge. Many of their addresses in the data base were no longer valid as most of them were using their college email accounts. The researcher embarked on a systematic search for these students. A check was made with the NUS to see if these students were enrolled in NUS. For those who had gone overseas, the researcher called the family to find out the name of the foreign university. For those whose telephone numbers were no longer in use, checks were made with their school mates or SRP mates. A third source of information was the scholarship granting agencies, many of which had a list of scholars on their website.

Having received the names of the overseas universities, the researcher used the search function on the university websites to get the students' contact details. At least 40% of the Cohort 2 students enrolled in foreign universities were tracked down in this manner. Contacting the Cohort 3 students was the most challenging as their contact details were 15 years old, and mostly outdated. After futile attempts to reach the majority of them, the researcher used the internet to search for them, and encountered problems that were unexpected. First of all, some of the girls had married and used their married names. Second, many of the students had used their Romanized Chinese names as students, but were now using their English names. The hours of 'googling' using different versions of their names paid off, as it led to the successful tracing of one third of Cohort 3 participants. All these measures contributed to the respectable rate of return on all surveys of 80%. The breakdown for Cohorts 1, 2 and 3 were 95%, 80% and 58% respectively.

Data analysis

Descriptive statistics were used to compute the frequency, percentages, means, standard deviations of data collected, and for within cohort analyses on applicable sections. Non-parametric statistics, t-tests and one-way analysis of variance (ANOVAs) were used to compare differences between cohorts on various dimensions.

Although Bonferroni corrections are typically used to correct for Type I error when multiple comparisons are conducted, as the more comparisons are made, the greater the probability of obtaining significant differences purely on the basis of chance (Newton & Rudestam, 1999), no Bonferroni procedures were adopted for this exploratory study, and therefore statistical significance at the $p<.05$ levels would be interpreted with caution as they could be due to experiment-wise error.

Open-ended responses were coded for themes to systematically identify clear and consistent patterns of phenomena (Marshall & Rossman, 1995) and analyzed to corroborate or elaborate the research in question. Where appropriate, comments from respondents were included to reflect an emic perspective (Rossman & Rallis, 2003).

Limitations of the study

There are weaknesses inherent in the design of this cross sectional survey study that is solely dependent on self-reporting data. Schwarz (1999) raised the concern that researchers are often not aware of the information in survey questionnaires that could shape the answers respondents give. Two of the cohorts had to answer questions retrospectively, and the accuracy of their responses could suffer from imperfect memory, reflections colored by present perspectives, and "distortion of hindsight" (Subotnik & Arnold, 1995).

The same two cohorts would have additional educational experiences at the tertiary level. Multiple-treatment interference posed a threat to external validity as it would not be known to what extent students' responses were influenced by other treatments. Events that had occurred during the 15-year lapse for the third cohort may affect them in a way that would not be true for the two younger cohorts. History and maturation could thus be a source of threat to internal validity (Gall et al, 2003). For instance during the last 15 years, Singapore suffered from two economic recessions. Did these impact the course and career decisions of the third cohort? More science research facilities had been built in the last five years, and more incentives given to attract gifted science students to pursue high level courses in the sciences. In 2003, the quota on the number of women doctors was abolished, resulting in more females being admitted to the faculty of medicine in the local university. How had these developments affected the 21-year olds in Cohort 2?

As subjects were spread over a wide geographical area, the most practical way to gather data was to use a questionnaire. The drawback of this is that questionnaires cannot probe respondents' beliefs, attitudes, and inner experiences deeply. In the pilot, while there was a 100 per cent return rate, yet only about 35% of respondents answered the open ended questions, and their answers were very brief, leading to the decision not to include too many open-ended questions.

Delimitations of study

The study was delimited by the deliberate decision to focus on participants of the SRP. This decision was made because the SRP is one of the very few programs that screens and selects participants using procedures based on the measure of aptitudes in a *specific* domain; in this case, the domain of scientific giftedness. The time frame for the research made it impossible to study all 17 cohorts of SRP participants. The first and second cohorts were not chosen because of the relatively smaller sample size. The program for the 17th cohort would end only in March 2005; hence the choice of the 16th Cohort instead. The choice of the 13th Cohort, as mentioned was to include both male and female participants who were still enrolled in university. The males would have just completed National Service, and matriculated as first year students, while the females would be in their third year of studies. In spite of the inherent weaknesses of the cross-sectional study, such a design was chosen to illuminate the developmental path of scientifically gifted students in the SRP.

Ethical considerations

This study proposal was submitted to the Human Subjects Review at the College of William and Mary. The three cohorts of SRP participants were informed that their participation in the study was voluntary. They were assured of anonymity as only aggregated data would be reported.

Conclusion

The procedures used to gather data in this study were described in the foregoing pages. In the next chapter findings for each of the research questions will be summarized and reported.

Chapter 4

Findings

Introduction

This was a retrospective study of three cohorts of students who participated in the Science Research Program (SRP), a mentorship program for high school students gifted in science. One hundred and fifty-five students participated in the study. Of these, 73 were those who participated in the SRP in Y2003, 52 were in the Y2000 SRP cohort, and 30 were from the Y1991 cohort. Data were collected during the period between the end of October and December 2004. This chapter summarizes the findings of the study. Section One provides the demographic profile of the students who responded to the survey. Section Two focuses on each of the research questions, and where applicable, other unanticipated findings that emerged. The third section summarizes the findings across the research questions.

Sample

The total number of students in the three cohorts was 223: 77 in each of the first two cohorts and 69 in the third. Students who could not be contacted after three attempts using different means (phone, conventional mail and email) were classified as 'uncontactable'. Since Cohort 1 students were still in Junior College (high school) at the time the survey was administered through their schools, none of them fell into the 'uncontactable' category. Twelve from Cohort 2 and 17 from Cohort 3 were 'uncontactable'. This brought the number of students who received the invitation to participate in the study to 194. Of these, 155 (80%) responded. The response rate by cohort was as follows: 95% for Cohort 1, 80% for Cohort 2 and 58% for Cohort 3. In terms of gender, 78% of boys and 85% of girls returned the survey, as shown in Table 5.

Table 5

Cohorts, and response rate by gender

Cohort size	Cohort 1		Cohort 2		Cohort 3		Total	
Gender	#		#		#		#	
Male	58		54 (44)		53 (40)		165 (142)	
Female	19		23 (21)		16 (12)		58 (52)	
Total	77		77 (65)		69 (52)		223 (194)	
Response rate	#	%	#	%	#	%	#	%
Male	54	93	33	75	24	60	111	78.2
Female	19	100	19	90	6	50	44	84.6
Total	73	95	52	80	30	58	155	80

Numbers in parenthesis reflect number left after discounting those who were uncontactable.

Based on Section I of the questionnaire, the demographic results for birth order, family income and parents' educational levels and occupational status were as follows.

Birth order

The SRP participants came from relatively small families, with a mean of 2.3 children. Sixty per cent of them were first-born, and 30% were second-born. A higher percentage of females (73%) than males (55%) were first-borns. While 21% of girls were only children, only 6% of boys came from single-child families. In fact for Cohort 1, 18 of the 19 girls (94.7%) were first-borns, and of these, seven (37%) were only children.

Family income

Not all students completed the information pertaining to household income and father's and mother's educational levels, and occupational status. Of those that did, 33.1 % were from the lowest quartile, compared to 25.4% in the highest quartile. If income levels were divided into two, about 60% of students came from lower income backgrounds. However, in absolute numbers, there were almost twice as many students from homes with the highest (31) income bracket (>$122,000) than there were for the lowest (17) bracket (<$22,000). (See Table 6).

Table 6

Family Income

	Cohort 2003 (N= 69)	Cohort 2000 (N=48)	Cohort 1991 (N=25)	Total (N= 142)
< $22000	11	5	1	17
bet $22001 & $32000	7	8	4	19
bet $32001 & $42000	2	7	2	11 {33.1 %
bet $42001 & $52000	6	2	3	11
bet $52001 & $62000	8	5	3	16
bet $62001 & $72000	4	6	1	11
bet $72001 & $82000	5	2	2	9
bet $82001 & $92000	3	0	1	4
bet $92001 & $102000	4	2	2	8
bet $102001 & $112000	2	0	0	2
bet $112001 & $122000	1	1	1	3
>$122001	16	10	5	31 { 25.4%

Parents' educational level

The educational levels of fathers and mothers are presented in Tables 7 and 8. For the fathers, while 57 (37.7%) had high school qualifications or lower, 73 (48.3%) had at least a baccalaureate degree or beyond. Again if educational levels were collapsed into two levels (vocational education and below and polytechnic education and above), 41% of SRP participants' fathers belonged to the first category of less education while 58% were better educated. For mothers, the pattern was reversed. Eighty-eight (52.8%) of them had high school or lower qualifications, while 53 (35%) had at least a university degree. In terms of the two levels (vocational education and below and polytechnic education and above), 61% of SRP participants' mothers were in the lower level, while 39% were in the higher level.

Table 7

Father's educational level

	Cohort 1 (N= 72)	Cohort 2 (N=50)	Cohort 3 (N=29)	Total (N= 151)
Below Junior College	19	19	8	46 {
Junior College	6	1	4	11 {
Vocational Institute	4	1	0	5 { 41%
Polytechnics	4	8	4	{16
University degree	20	15	8	{43
Post graduate degree	19	6	5	59%{30

Table 8

Mother's educational level

	Cohort 1 (N= 72)	Cohort 2 (N=50)	Cohort 3 (N=29)	Total (N=151)
Below Junior College	25	22	14	61{
Junior College	12	10	5	27 {
Vocational Institute	4	0	0	4 { 61%
Polytechnics	2	2	2	{ 6
University degree	18	13	6	{37
Post graduate degree	11	3	2	39%{16

Parents' occupational status

Students were given 16 categories of occupations to indicate their parents' occupational status at the time when students were in the SRP. If the occupational categories were classified according to the nature of work and unemployed and self employed were excluded, about 30% of participants' fathers were in the highest level occupations, while 7% were in the lowest level. (See Table 9). The distribution for mothers' occupational status was 5% of them in the lowest level, and 31% in the highest. (See Table 10). Among the occupations in the lowest category were laborer, factory worker, cleaner, and driver. Included in the highest level occupations were doctors, lawyers, bankers, administrators. It is interesting to note that 60 (40%) mothers were stay-at-home mothers, and of these, 20% had polytechnic and higher educational qualifications. By contrast, 16 fathers (10.7%) were stay-at-home fathers. Of these, 69% of them had a polytechnic or higher education. This percentage of highly qualified stay-at-home fathers could be attributed to the two economic recessions that hit Singapore between 1997 and 2003. The recessions were probably also accountable for the relatively high percentage of self-employed parents.

Table 9

Father's occupational status

Occupation category	#	%
Unemployed/retired	16	10.7{
Laborer	1	.7 {
Factory/construction worker	0	0 {
Driver	10	6.7{ 18.1
Food services/restaurant	0	0
Skilled craftsmen	6	4
Retail sales, clerical, customer service	6	4
Service technician	8	5.2
Bookkeeping/accounting/related administrative	5	3.4
Singer/musician/artist/writer/actor	0	0
Real estate/insurance agents	2	1.3
Public service/social service, governmental	21	14.1
Military/police	2	1.3{
Teacher/nurse	10	6.7{
Professional/executive	34	22.8{
Self employed	28	18.8{49.6

Table 10

Mother's occupational status

Occupation category	#	%
Unemployed/retired	60	40 {
Laborer	1	.7 {
Factory/construction worker	2	1.3 {
Driver	0	0 { 43
Food services/restaurant	1	.7
Skilled craftsmen	4	2.7
Retail sales, clerical, customer service	3	2
Service technician	0	0
Bookkeeping/accounting/related administrative	7	4.7
Singer/musician/artist/writer/actor	0	0
Real estate/insurance agents	3	2
Public service/social service, governmental	11	7.3
Military/police	0	0 {
Teacher/nurse	27	18{
Professional/executive	20	13.3{
Self employed	11	7.3 {38.6

Another part of Section I of the questionnaire required students to report on their involvement in the Gifted Education Program (GEP), co-curricular activities as well as awards they had won. Additionally, they had to report their grades for the three sciences and mathematics, their special paper candidature as well as their favorite subject. The following section summarizes the findings for these areas.

GEP status

Half of the participants (78) were from the Gifted Education Program. Of the 78, 55 (70.5%) were boys, and 23 were girls. In terms of distribution by cohort, exactly 50% of Cohort 2 participants were from the GEP. The percentage was higher for Cohort 1 (53.4%), and lower for Cohort 3 (43.3%). Regardless of GEP status, the vast majority of them were from the more established schools in Singapore: 114 of the 155 respondents studied in one of the top five ranking secondary schools, while 143 of them were in one of the top five ranking junior colleges.

Co-curricular activities

It is mandatory for all students in Singapore schools to participate in at least two co-curricular activities – one in the area of sport or uniformed group and the other in a club. Among the SRP respondents, there were a few interesting trends. First of all, more boys than girls were involved in science-related clubs as evident in Table 11.

Table 11

Participation in science-related clubs by gender

	Cohort 1		Cohort 2		Cohort 3		Total	
	#	%	#	%	#	%	#	%
Male	N=53		N=27		N=20		N=100	
	23	43.4	14	51.9	8	40	45	45
Female	N=19		N=19		N=4		N=42	
	5	26.3	1	5.3	1	25	7	16.7

The two groups of sports that appeared to be most popular among SRP participants were athletics, air rifle and archery, and the 'defense' sports of judo, fencing, taekwondo and wushu. Twenty-one of them were involved in the first group, and another 21 in the second group. The most popular non-science related club was chess/bridge. Forty-two of them (29.5%) reported being involved in a band, orchestra, dance or choral group. Twenty three were active in community service clubs while 18 were student leaders. On the whole, the SRP students had a spectrum of interests and were by no means involved only in science-related activities. (See Appendix D for the range of co-curricular activities).

Awards

One hundred and eighteen students reported having won at least one award, and of these 46 (39%) of them had won award(s) in science competitions including the National Science Talent Search, the Singapore Science and Engineering Fair, the Intel Science and Engineering Fair, and the Academic Olympiads in biology, chemistry, physics, mathematics and information technology. It is worth noting that all 46 award winners were from Cohorts 1 and 2. This is because these competitions were introduced in Singapore only in the mid 1990s after Cohort 3 students had graduated from high school. Among the 46 science award winners, 26 of them had won it in one or more Academic Olympiads at the national and/or international level. Of the 26, 21 (80.8%) of them were boys. This trend in favor of boys was even more evident when it came to publications. Five respondents, all males, reported on their publications. Two of them were from Cohort 1, one from Cohort 2, and two from Cohort 3. One of the two from Cohort 3 also owned patents.

Mathematics and science grades

The trend in favor of males was reversed when it came to academic grades as evident in Table 12 which shows the percentage of students who scored at distinction (i.e. an A grade) in mathematics, biology, chemistry and physics. Physics was the only exception, with the boys performing better than the girls.

Table 12

Students scoring at distinction in math and the sciences by gender

	Biology		Chemistry		Physics		Math	
	#	%	#	%	#	%	#	%
Male	53	18.6	67	61.5	78	71.6	100	91.7
Female	21	18.8	28	65.1	29	67.4	40	93.0

Enrolment for 'S' papers

The Special ('S') paper is pitched at a level higher than the 'Advanced' ('A') level for the General Certificate in Education (GCE) 'A' Level exams, and is an optional paper targeted at students who are particularly able in a specific subject. The 'S' paper can be said to be the equivalent of the Advanced Placement course offered by the College Board in the USA. The course is pitched at college level, and carries special weight for admission to certain universities and applications for scholarships. 'S' paper courses are very rigorous and make exacting demands on students who are expected to do quite a bit of independent learning. Students do these 'S' papers *in addition* to their 'A' level papers. To ensure that enrolment in the 'S' papers does not adversely affect students' performance in the 'A' level subjects, schools impose stringent criteria on 'S' paper candidates. Table 13 shows the 'S' paper enrolment while Table 14 shows the correlations between grades in 'A' level subjects and 'S' paper enrolment.

Table 13

'S' paper candidature by cohort and gender

	Biology		Chemistry		Physics		Math	
	#	%	#	%	#	%	#	%
Cohort 1								
Male	11	21.1	27	51.9	33	44.2	22	42.3
Female	4	21.0	11	57.9	8	42.1	12	63.2
Cohort 2								
Male	8	25	13	40.6	16	50	23	71.9
Female	3	15.8	8	42.1	11	57.9	11	57.9
Cohort 3								
Male	11	47.8	10	43.5	7	30.4	13	56.5
Female	0	0	1	25	0	0	3	75

Since SRP participants were selected for the program by virtue of their excellent performance in math and/or science, it is expected that all of them should enroll in at least one 'S' paper in these subjects. However, 16 of them did not take any 'S' papers. Of the 16, 12 were boys, of which 8 were from Cohort 1. In fact for Cohort 1 students, there were more girls than boys enrolled in 'S' chemistry and 'S' math. It is interesting that the Cohort 2 girls outnumbered the boys in 'S' physics, a traditionally male-dominated subject, but that was also the only cohort where the enrolment for 'S' math was higher for the boys than the girls. Table 14 shows a significant correlation between grades and enrolment in 'S' papers, except for Physics.

Table 14

Pearson's correlation between grades in 'A' levels and enrolment in 'S' papers

	'S' biology	'S' chemistry	'S' physics	'S' math
Biology	.357***			
Chemistry		.266**		
Physics			.119	
Math				.273**

*** $p \leq .000$
** $p \leq .001$

As 'S' paper candidates are expected to devote more time, effort and resources to their 'S' papers, one would expect that they would sign up for 'S' papers that they enjoyed studying. However, the data show that students were not signing up for 'S' papers for their favorite subject. (See Table 15). Their enrolment in 'S' papers seemed to be motivated by other factors, and not 'love of the subject'. Granted, a student can take more than one subject at 'S' level but would declare only one favorite subject. At the very least then, one would expect the percentage for an 'S' subject to be no less than that for the favorite subject. Take the case of the girls: less than half of them who declared biology as their favorite signed up for 'S' biology. Yet, three times as many girls signed up for physics, compared to the number who said physics was their favorite subject. The trend was the same for boys across the four subjects. It appears that *other* factors were at play in students' decision to enroll for 'S' papers.

Table 15

Students' favorite subject and enrolment in 'S' papers by gender

	Male				Female			
	'S' paper enrolment		Favorite subject		'S' paper enrolment		Favorite subject	
	#	%	#	%	#	%	#	%
Biology	30	27.8	38	40	7	16.7	14	34.1
Chemistry	50	46.3	20	21.1	20	47.6	9	22.0
Physics	56	51.9	18	18.9	19	45.2	6	14.6
Math	58	54.2	19	20	26	61.9	12	29.3

Other information

Findings from two other questions in the questionnaire that are not directly related to the research questions will be reported here. One of the questions pertained to SRP students' views on acceleration. The SRP which seeks to provide gifted high school science students an early exposure to the methodology and techniques required in research is an accelerated program which matches students to research scientists and mathematicians who serve as mentors. At the time the questionnaire was administered, there was some debate in the Singapore media about the desirability of acceleration as an educational option. The researcher was interested to find out if SRP participants were in favor of acceleration. The question posed was "There are people who believe that children who show exceptional abilities should be allowed to be accelerated and proceed at their own pace, ahead of their age peers. What are your views on this practice?"

Of the 155 respondents, 17 either did not answer the question or had no comment; another 12 disagreed with the practice, while 126 (81%) supported the practice, though not without any reservation. The reasons offered in support of acceleration can be organized into several themes, as reflected in the quotes of the proponents. The first is disallowing acceleration would result in boredom, leading to loss of interest and extinguishing of talent. A Cohort 1 female shared her personal experience: "I absolutely agree [with acceleration]. In lower primary, I was secretly reading my own books in class because I was bored with the lesson. I ended up disrupting the class because the teacher had to tell me to stop. School became more interesting after I was transferred to the GEP." A Cohort 2 female opined: "It makes sense...If a child were forced to learn things slower despite his exceptional ability, he would probably become very bored...and he might lose interest in the subject", interest, which to another Cohort 2 male, "that is very hard to re-kindle later". Yet another Cohort 2 male wrote passionately: "I strongly agree. I have seen many examples where people with potential were hindered by the rigidity of the [educational system]. It is really very upsetting to see the potential being leashed, and worse diminished after a period of stagnancy. The education system should not be a barrier for such people. Instead, it should be a launching pad for them to fly." A second theme in favor of acceleration relates to honoring individual differences. A Cohort 1 male offered this view: "I believe different people are born to be good at different things. Therefore a child gifted in a certain area should be allowed to excel."

His male school mate concurred: "To deprive the child of the opportunity to learn faster than the traditional system would allow is akin to disallowing a gifted sporty child from playing his sport of interest." A Cohort 1 female touched on the issue of fairness: "Every student should be allowed to learn at his own pace, to be fair to the child, and his intellectual ability…" Since not everyone learns at the same rate, and not everyone is good in every field, "Why hold the child back for the sake of uniformity? What good can come out of stifling a gifted child?" a Cohort 3 male asked rhetorically. A third theme offered in support of acceleration had to do with pragmatism – a society bereft of natural resources cannot afford to squander its talent. A respondent put it simply: "I absolutely agree with [acceleration]. Simply we need elites in the scientific careers and early development will be necessary for potential scientists." Another counseled that "failure to [allow individuals to proceed at own pace to develop potential] will be a huge cost to society. Talk about elitism is myopic and misses the point…" Both males were from Cohort 1. A final theme had to do with national examinations, and how they impede advanced students' progress. A Cohort 3 male wondered "why all students should take all their exams at the same time." He elaborated: "…there is no reason why children who wish it, and if the school thought they were sufficiently prepared, should not take the 'O' level exam at a younger age…" A Cohort 2 female who had the same thought elaborated thus: "…these children should be allowed to take certain national exams earlier; for example, a child who excels in math should be allowed to take his Primary School Leaving Examination in math earlier, in Primary 4, [instead of waiting till Primary 6]. Then he can use the time to further develop his passion for math or spend more time on his weaker subjects…" Regardless of the reasons proffered in support of acceleration, the students stressed the need for balance – that care should be taken to ensure that accelerants should not be isolated and that they have ample opportunity to interact with and relate to people different from themselves. As a Cohort 2 male put it: "A balance has to be struck between academic excellence and social interaction."

Those who opposed acceleration interpreted it as a practice which meant full-time separation of accelerated children from their age peers. To a female from Cohort 2, "Every child should have a proper childhood...If they are indeed geniuses in their own ways, they would be able to excel later in life, without any acceleration in their study program". To a Cohort 3 male, he equated acceleration with 'narrowing' of educational experiences. He wrote: "Allowing skipping of grades and taking exams ahead of [my] peer group I feel is counterproductive. Hot housing is out. It is fine to encourage accelerated development of unique talents at the pace of the child (e.g. math, music, oratory skills etc. if necessary by enrichment programs, SRP etc.) but also ensure wide exposure to all subjects that child would not normally be involved with. Breathing space and allowing children the opportunity to develop and pursue own interests independently are invaluable..." Another objection to acceleration was the issue of equity. As one Cohort 2 male put it: "Segregating the 'high fliers' will only worsen the divide between them and the less able. [The latter] will do well if they can find motivation from those who are doing well, and are willing to share." One main concern of the opponents of acceleration was the asynchronous development of academically gifted children. To quote a Cohort 1 female: "While these children may be ahead academically, they could still be deficient socially or in other areas...the ability to relate to age peers of lesser ability is equally important". Indeed her concern is shared by those who support acceleration but have reservations because of its social ramifications. They feel it is equally important for the brightest to be able to relate to people with different abilities.

Many of the proponents of acceleration cited the SRP as one way to accelerate the academically talented – allowing academically talented students to remain with age peers for the major part of the school day, and allowing them to attend special programs or higher classes in their area of talent outside school hours. Based on the majority of the responses, it appears that SRP students are in favor of acceleration, but not if it takes the form of grade skipping.

Another question that was posed to SRP participants was if they would be willing to volunteer as a mentor in the SRP. Of the 151 who responded to this question, 105 (70%) of them answered in the affirmative. By cohort, the percentage was 70% of Cohort 1, 80% of Cohort 2 and 55% of Cohort 3 students. The breakdown by gender was 66% for males and 77% for females.

Question #1 Results

Research question #1 sought to find out what factors contributed to SRP students' early interest in science, the extent to which these factors were intrapersonal or external, and if there was a significant difference for male and female participants.

Participants were asked to rank 15 items on a scale of 1 to 4 to indicate the extent to which the item (factor) contributed to their early interest in science. The percentage of students who agree/strongly agree with the items is given in Table 16. As can be seen, all the factors in this scale were 'external' factors, pertaining to the school or the home. Across all three cohorts, and for both boys and girls, the 'school' factors garnered high percentages of agreement, and had higher means. Four of the five most highly rated items had to do with school: "encouraging teachers", "stimulating lessons in school", "good grades in science", "enrichment activities". The last factor that could apply to both the school and the home was "freedom to explore my own interests". By contrast, ‘home’ factors registered lower degrees of agreement: “influence of siblings” (17%), “leisure time with family” (34%) and “parental influence” (37%). The strongest ‘home’ influence was “presence of non fiction resources” (69%).

One-way Analysis of Variance (ANOVA) was performed to see if the differences between the means for boys and girls were statistically significant, and they were for the following items: “good grades in science”, “freedom to explore own interests”, and “presence of non fiction resources”, with the first favoring girls, and the latter two favoring boys. (See Appendix E1 for the ANOVA results and Table 17 for the summary). Bonferroni corrections are typically used to correct for Type I error when multiple comparisons are conducted, as the more comparisons are made, the greater the probability of obtaining significant differences purely on the basis of chance (Newton & Rudestam, 1999). But Bonferroni corrections are also known to have the effect of reducing power, and increasing Type II error, as the more variables a researcher measures, the less probability of finding significant results (Nakagawa, 2004). Bonferroni corrections and overemphasis on statistical significance by journal reviewers could thus discourage exploratory data analyses that might uncover potential research directions (Cohen, 1990). Since this is an exploratory study, no Bonferroni corrections were made; statistical significance at the $p<.05$ levels could therefore also be due to experiment-wise error.

All but one of the girls (97.7%, M=3.5) indicated that their interest in science could be attributed to their good grades, while 82.8% (M=3.2) of boys were so motivated. However, fewer girls (88.6%, M=3.2) than boys (92.8%, M=3.4) agreed that they had “freedom to explore own interests”, and that “presence of non fiction resources at home” added to their interest in science (62.8%, M=2.7 compared to 71.1%, M= 3.0 for boys).

Girls also seemed to perceive co-curricular activities as not contributing much to their interest in science, with only 36.4% (M=2.3) of them agreeing with this item. This was probably due to their choice of co-curricular activities in school. (cf Table 11).

Table 16

Factors contributing to students' early interest in science

	#	M	SD	# Agree	%
Stimulating lessons in school	155	3.15	.643	135	87.1
encouraging teachers	155	3.37	.605	145	93.6
Inspiring role models (e.g. teacher or parent passionate about science)	155	3.08	.698	131	80.6
Availability of resources in school	155	2.93	.704	107	75.5
Enrichment activities	155	3.23	.679	135	87.1
Good grades in science	155	3.29	.756	135	87.1
Peers with similar interest	155	2.97	.793	116	74.8
co-curricular activities	155	2.45	.799	69	44.5
Parents work in science field	155	1.91	.825	30	19.4
parental influence	155	2.24	.898	57	36.7
freedom to explore own interests	155	3.37	.676	142	92.6
presence of non fiction resources at home	154	2.89	.845	106	68.8
leisure time with family	155	2.27	.800	52	33.5
influence of siblings	135	1.90	.800	23	17.1
Enrolment in enrichment programs	155	3.06	.808	121	78.1

Table 17

Factors contributing to students' early interest in science by gender

	Male				Female			
	#	%	M	SD	#	%	M	SD
Stimulating lessons in school	96	86.5	3.13	.648	39	88.6	3.20	.632
Encouraging teachers	104	93.7	3.37	.602	41	93.2	3.39	.618
Inspiring role models	85	76.5	3.03	.732	40	81.9	3.20	.594
Availability of resources in school	83	74.7	2.95	.749	34	77.3	2.89	.579
Enrichment activities	96	86.4	3.23	.700	39	88.6	3.20	.632
Good grades in science	92	82.8	3.20	.807	43	97.7	3.52	.549**
Peers with similar interest	84	75.6	3.00	.820	32	72.7	2.89	.722
co-curricular activities	53	47.7	2.50	.873	16	36.4	2.32	.561
Parents work in science field	20	18.0	1.87	.854	10	22.8	2.00	.747
parental influence	38	34.2	2.18	.916	19	43.2	2.39	.841
Freedom to explore my own interests	103	92.8	3.44	.683	39	88.6	3.20	.632*
Presence of non fiction resources at home	79	71.1	2.97	.858	27	62.8	2.67	.778*
Leisure time with family	38	34.2	2.28	.833	14	31.8	2.25	.719
Influence of siblings	15	14.7	1.87	.804	8	24.2	2.00	.791
Enrolment in enrichment programs that emphasized science learning	84	75.6	2.99	.837	37	84.1	3.23	.711

** $p < .01$
* $p < .05$

Analysis by cohort showed that Cohort 3 students' rating of "enrichment opportunities" was much lower compared to those of Cohorts 1 and 2, and this difference was statistically significant at the $p<.01$ level ($F= 4.873$, $df=2$, $p=.009$). Their rating of "enrolment in enrichment programs that emphasized science learning" was also much lower that those of their younger counterparts, although the difference between means was not statistically significant. This could be due to the fact that over the last fifteen years, more and more enrichment options have been added to the school program, and younger students have had greater access and choice. More Cohort 3 students attributed their interest in science to parental influence (43%), compared to about 35% for Cohorts 1and 2. However, Cohort 3 students (87%, M=3.1) also felt that they had less "freedom to explore own interests", compared to the younger students (94%, M=3.4). These results are summarized in Table 18, while the ANOVA results are in Appendix E2.

Table 18

Factors contributing to students' early interest in science by cohort

	Cohort 1				Cohort 2				Cohort 3			
	#	%	M	SD	#	%	M	SD	#	%	M	SD
Stimulating lessons	65	89.0	3.10	.605	46	88.5	3.31	.673	24	80	3.00	.643
Encouraging teachers	68	93.2	3.36	.609	49	94.2	3.46	.609	28	93.3	3.27	.583
Inspiring role models	63	86.3	3.11	.657	41	78.9	3.10	.721	21	70.0	2.97	.765
Availability of resources in school	53	72.6	2.96	.716	42	80.8	2.94	.639	22	73.4	2.83	.791
Enrichment opportunities	66	89.9	3.26	.624	48	92.3	3.37	.627	21	70.0	2.90	.803**
Good grades in science	59	80.8	3.18	.805	48	92.3	3.46	.753	28	93.3	3.27	.583
Peers with similar interest	62	84.9	3.11	.678	37	71.2	2.83	.879	17	56.7	2.87	.860
Co-curricular activities	37	41.7	2.55	.851	19	16.6	2.31	.755	13	43.4	2.43	.728
Parents work in science field	17	23.3	2.03	.781	9	17.3	1.81	.864	4	13.4	1.80	.847
parental influence	26	35.6	2.27	.838	18	34.6	2.15	.958	13	43.3	2.30	.952
freedom to explore my own interests	67	91.8	3.42	.686	49	94.2	3.44	.608	17	86.7	3.13	.730
presence of non fiction resources at home	53	73.6	2.96	.813	43	63.5	2.81	.864	20	66.7	2.87	.900
leisure time with family	29	39.7	2.37	.791	13	25.0	2.15	.802	10	33.4	2.23	.817
influence of siblings	13	17.8	2.03	.830	6	13.0	1.80	.778	4	13.3	1.80	.761
Enrolment in enrichment programs	58	79.4	3.07	.770	44	84.6	3.19	.841	19	63.3	2.80	.805

** $p<.01$ (Tukey's post hoc showed that the difference was between Cohort 3 and Cohort 2, and Cohort 3 and Cohort 1.

As mentioned, the fifteen factors in the first scale dealt with external factors. What were the intrapersonal factors that contributed to students' early interest in science? According to the *American Heritage Dictionary of the English Language: Fourth Edition (2000),* intrapersonal means "existing or occurring within the individual self or mind". Students were given a list of 29 traits which, according to the research literature, were common among talented teens gifted in math and science, and asked to check those traits that applied to them. The traits were grouped and organized in descending order of frequencies in Table 19. It is evident that the intrapersonal traits were the most frequently checked traits. Apart from abilities, intrapersonal traits like curiosity, persistence, conscientiousness and intuition had among the highest frequencies. Chi squares showed that the number of students with these traits was greater than expected by chance. The "external" items like activities they enjoy had comparatively lower frequencies.

Analyzed by gender, cross-tabs showed that seven of the items (traits) were related to gender. The differences between boys and girls on the following traits were statistically significant: curious about how things work, independent learner, strong spatial ability, like to tinker with things, love to experiment, enjoy jigsaw puzzles and enjoy the outdoors, all of which favored the boys except for the last two traits where a higher percentage of girls than boys checked them. On the other intrapersonal traits like persistence, intuition and conscientiousness, there were no statistically significant differences between the sexes.

Table 19

Traits of SRP participants

Traits	All Cohorts				Male (N=110)		Female (N=44)		Cross tabs	
	#	%	x^2	*p*	#	%	#	%	x^2	P
Curious about how things work	135	87.7	87.377	.000***	102	92.7	33	75.0	9.132	.005**
Work hard at something I like	114	74.0	35.558	.000***	82	74.5	32	72.7	.054	.816
Independent learner	114	74.0	35.558	.000***	87	79.1	27	61.4	5.137	.027*
Learn things very quickly	107	69.5	23.377	.000***	73	66.4	34	77.3	1.764	.184
Always questioning how things work	101	65.6	14.961	.000***	77	70.0	24	54.5	3.326	.068
Persistent	95	59.1	37.506	.024*	66	60.0	25	56.8	.132	.717
Intuitive	90	58.4	4.390	.036*	65	59.1	25	56.8	.067	.796
Dissatisfaction with explanation of present phenomena	34	22.1	48.026	.000***	27	24.5	7	15.9	1.363	.243
Good at seeing patterns	116	75.3	39.506	.000***	86	78.2	30	68.2	1.691	.193
Strong spatial ability	74	48.1	.234	.629	59	53.6	15	34.1	4.840	.033*
Observant about nature	72	46.8	.649	.420	49	44.5	23	52.3	.754	.385
Fascination with numbers	67	43.5	2.597	.107	47	42.7	20	45.5	.095	.758
Enjoy problem solving	115	74.7	37.506	.000***	82	74.5	33	75.0	.003	,953
Like to tinker with things	88	57.1	3.143	.076	74	67.3	14	31.8	16.132	.000***
Love to experiment	86	55.8	2.104	.107	68	61.8	18	40.9	5.572	.021*
Enjoy the outdoors	75	48.7	.104	.747	48	43.6	27	61.4	3.953	.052*
Love to collect things	75	48.7	.104	.747	50	45.5	25	56.8	1.625	.202
Enjoy jigsaw puzzles	68	44.2	2.104	.107	37	33.6	31	70.5	17.278	.000***
Enjoy solitary activities	66	42.9	3.103	.076	50	45.5	16	36.4	1.061	.303

Table 19 (contd.)

Traits					Male (N=110)		Female (N=44)		Cross tabs	
	#	%	x^2	*p*	#	%	#	%	$\square^2$	P
Love to read non fiction	67	43.5	2.597	.107	52	47.3	15	34.1	2.222	.136
Enjoy the arts and aesthetics	58	37.9	8.948	.003**	37	33.6	21	48.8	3.035	.081
Love to study design	45	29.2	26.597	.000***	33	30.0	12	27.3	.113	.737
Competitive	98	63.6	11.455	.001**	68	61.8	30	68.1	.550	.458
Enjoy intellectual discussions with peers	94	60.6	7.506	.006**	68	61.8	26	59.1	.098	.754
Interest in current affairs	62	40.3	5.844	.016**	48	43.6	14	31.8	1.825	.177
Interested in new scientific developments	89	57.8	3.740	.053*	68	61.8	21	47.7	2.558	.110
Would like to contribute to society	82	53.2	.649	.420	59	53.6	23	52.3	.023	.878
Sense of destiny	32	20.8	52.597	.000***	26	23.6	6	13.6	1.909	.167
Aspire to get a university degree	90	58.4	4.390	.036*	60	54.5	30	68.2	2.406	.121

*** p<.001
** p<.01
* p< .05

Yet another section of the questionnaire shed some light on the intrapersonal factors that prompted these students to participate actively in science activities, like the SRP. Students were given 13 reasons that could have prompted them to participate in the SRP. From the descriptive statistics presented in Table 20, it is evident that students did not respond to **"external"** influences: parents or siblings or teachers or peers. These had the lowest degree of agreement, based on mean scores: 1.64, 1.50, 2.44 and 1.83, respectively. The highest rated items by mean scores were: to find out what scientific research was like (M=3.43), to get a glimpse of the life of the scientist (M=3.41), to see if I have what it takes to be a to be a scientist/researcher (3.28), to be able to research an area of interest in depth (M=3.22), and to observe scientists/researchers at work (M=3.14). They wanted to find out what research was like, what the life of a researcher was like and if they had what it takes to be a scientist. They were willing to take on the additional challenge of a mentorship program and all its demands to fulfill their interests – they joined the SRP so that they could discuss research in depth with a mentor. The "external" factors were practical considerations – to enjoy the prestige (M=2.61), to enhance chances of getting a scholarship (M=2.51), and to gain access to state of the art facilities that they did not enjoy in school (M=2.94).

Table 20

Reasons for joining SRP

	#	M	SD	# agree	% agree
to observe scientists/researchers at work	155	3.14	.712	133	85.8
to be able to research an area of interest in depth	155	3.22	.657	135	87.1
to find out what scientific research is	155	3.43	.613	145	93.5
to follow up on teachers' encouragement	154	2.44	.731	65	41.9
to satisfy parents' desire to have me participate	154	1.64	.614	11	7.1
to respond to my peer group	154	1.83	.684	21	13.6
to benefit from the prestige of the program	154	2.61	.811	100	64.9
to improve the chances of getting a scholarship to university	154	2.51	.818	89	57.7
to have access to university labs and state of the art facilities	155	2.94	.808	116	74.8
to respond to a sibling who had been a participant who encouraged me	135	1.50	.584	4	2.9
to see if I have what it takes to be a scientist/researcher	155	3.28	.672	138	89.0
to get the glimpse of the life of a scientist	154	3.41	.601	147	95.5
to have a mentor to discuss my interests with	154	2.82	.727	107	69.5

Were the factors that motivated boys and girls to participate in the SRP different? One-way ANOVA showed that on four of the factors, the differences were statistically significant, and of these four, three of them were 'external' factors. (See Table 21). Girls, more than boys, tended to respond to teachers' encouragement and parental pressure. It is interesting to note too that girls more than boys participated in the SRP to enhance their chances of getting a scholarship. The difference was statistically significant at the p <.001 level. Moreover, the mean for girls (M= 3.59) for the item "to find out what scientific research is" was higher than that for boys (M=3.36), and the difference was statistically significant at the p<.05 level. (See Appendix E3 for ANOVA results).

Table 21

Reasons for joining SRP by gender

	Male		Female		F	Sig.
to observe scientists/researchers at work	93	83.8	40	90.9	1.594	.209
to be able to research an area of interest in depth	97	87.4	48	86.3	.515	.474
to find out what scientific research is	102	91.8	43	97.8	4.558	.034*
to follow up on teachers' encouragement	44	40.0	21	47.7	4.781	.030*
to satisfy parents' desire to have me participate	4	3.6	7	15.9	8.881	.003**
to respond to my peer group	16	14.5	5	11.4	1.336	.250
to benefit from the prestige of the program	66	70.0	34	77.3	3.255	.073
to improve the chances of getting a scholarship to U	55	50.0	34	77.2	10.504	.001***
to have access U labs and state of the art facilities	80	72.0	36	81.8	.613	.435
to respond to a sibling who encouraged me	3	2.7	1	2.3	.045	.832
to see if I have what it takes to be a scientist/researcher	98	88.3	40	90.9	2.150	.145
to get the glimpse of the life of a scientist	105	95.5	42	95.5	3.219	.075
to have a mentor to discuss my interests with	75	68.1	32	72.8	.540	.464

*** p<.001
** p <.01
* p<.05

Analysis by cohort revealed that family influence was not a factor with both "pressure of parent and influence of sibling" registering single digit per cent of agreement. All three cohorts also did not join the SRP because of the influence of peers, with 13% agreeing with this across all three cohorts The two factors that had more than 90% of respondents agreeing across the cohorts were "to find out what scientific research is" and "to get the glimpse of the life of a scientist". This shows that all three cohorts needed to know if they were suitable for a career in science research. For the remaining eight reasons, there were variations in the degrees of agreement across the cohorts, but the only one that was statistically significant was "to be able to research an area of interest in depth", with p at the <.05 level (F=4.084, df=2, p=.019), with 20% more Cohort 1 students than Cohort 3 students agreeing with it. The ANOVA results are in Appendix E4 and summarized in Table 22.

Table 22

Reasons for joining SRP by cohort

	Cohort 1 (N=72)		Cohort 2 (N=52)		Cohort 3 (N=30)	
	#	%	#	%	#	%
to observe scientists/researchers at work	66	90.4	40	76.9	27	90
to be able to research an area of interest in depth	69	94.5	44	84.6	22	73.3*
to find out what scientific research is	70	95.9	47	90.4	28	93.3
to follow up on teachers' encouragement	35	47.9	19	36.6	11	36.6
to satisfy parents' desire to have me participate	7	9.7	2	3.8	2	6.7
to respond to my peer group	10	13.9	7	13.4	4	13.3
to benefit from the prestige of the program	49	68.0	34	65.3	17	56.6
to improve the chances of getting a scholarship to U	43	59.4	34	65.4	12	40.0
to have access U labs and state of the art facilities	59	80.8	37	71.1	20	66.7
to respond to a sibling who encouraged me	3	5.1	1	2.2	0	0
to see if I have what it takes to be a scientist/researcher	68	95.8	45	86.6	25	83.3
to get the glimpse of the life of a scientist	69	95.8	49	94.3	29	96.7
to have a mentor to discuss my interests with	57	78.1	33	64.7	17	56.7

* p< .05

Summary of Question #1 findings

Both external and internal factors were important in stimulating SRP participants' early interest in science. Of the external factors, it was evident that SRP participants attributed greater importance to the role of the school and teachers than to their parents and the home. Girls, compared to boys, seemed more susceptible to external influences, with a higher percentage of them citing as reasons for participating in the SRP "to follow up on teachers' encouragement", and "to satisfy parents' desire" to have them participate. Being in the SRP was also perceived as more important to the girls (M= 2.84) than the boys (M=2.38) in enhancing their chances of winning a scholarship to university. Fewer students (40%) in Cohort 3, compared to the two younger cohorts (60%), joined the SRP to improve their chances of getting a scholarship. However, all three cohorts reported that their decision to join the SRP had little to do with parental pressure or influence of a sibling or peers, with the means for all three cohorts for these three reasons lower than 2.

As for the role of internal or intrapersonal factors, all three cohorts, and both girls and boys reported having traits that are characteristic of people gifted in science, and most of these traits are 'internal' in nature. These include a strong sense of curiosity, always questioning how things work, intuition, persistence, and working hard at something they like, traits which SRP students associated with successful scientists, as will be seen in a later section of this chapter.

Question #2 Results

The second research question focused on participants' perceptions about science and the influences on their talent development in the field. It also asked how the SRP had contributed to students' continuing work in science.

One of the questions in the survey asked students to list three essential traits of successful scientists. Table 23 shows in order of decreasing frequency the eight traits most cited by the students (N=144).

Table 23

Essential traits of successful scientists – Total frequencies across cohorts

Traits	Total (N=144)	%
Curious	56	38.8
Perseverance	46	31.9
Passion	41	28.5
Persistence	40	27.8
Creative	29	20.1
Determined	25	17.4
Intelligence	23	15.9
Diligent	20	13.9

It appears from these data that SRP participants perceived that science is hard work, and to succeed at it, one has to have the passion, intelligence and creativity to do the work. One has also to be curious enough – ask questions and seek answers to them. When working on experiments and research, one has to have determination, persistence and perseverance.

How did the cohorts differ in their perceptions? Table 24 summarizes the results.

Table 24

Essential traits of successful scientists by cohort

	Cohort 1 (N=69)		Cohort 2 (N=47)		Cohort 3 (N=28)	
Characteristic	#	%	#	%	#	%
Curious	23	33.3	17	36.2	16	57.1
Perseverance	21	30.4	15	31.9	10	35.7
Passion	22	31.9	13	27.7	6	21.4
Persistence	15	21.7	14	29.8	11	39.3
Creative	17	24.6	10	21.3	3	10.7
Determined	15	21.7	7	14.9	3	10.7
Intelligence	11	15.9	8	17.0	4	14.3
Diligent	11	15.9	7	14.9	2	7.1

All three cohorts placed the greatest importance on perseverance/persistence based on simple frequencies. Cohort 3 students seemed to place more importance on curiosity, compared to their younger counterparts (33.3%, 36.2%, and 57.1%). By contrast, the younger students seemed to think creativity was a more important trait (24.6%, 21.3%, and 10.7%).

When comparing the perceptions of males and females, the striking difference is in perseverance/persistence/determination; 93.0% of girls listed these qualities, compared to 70.3% boys. More girls (48.8%), compared to boys (34.7%) also thought curiosity was a necessary trait in order to be successful at science. More boys (17.8%) than girls

11.6%), however, felt that intelligence was essential for one to be a successful scientist. (See Table 25).

Table 25

Essential traits of successful scientists by gender

	Males (101)		Females (43)	
Trait	#	%	#	%
Curious	35	34.7	21	48.8
Perseverance	28	27.7	18	41.7
Passion	31	30.6	10	23.3
Persistence	27	26.7	13	30.2
Creative	17	16.8	12	27.9
Determined	16	15.8	9	20.9
Intelligence	18	17.8	5	11.6
Diligent	15	14.9	5	11.6

Whatever the differences were among the cohorts and between the sexes, all students agreed that science was hard work, and to be successful, one must be sufficiently curious and have great perseverance.

Impact of the SRP

Seven items to gauge the impact of the SRP on students' continuing involvement in science were given, and students were to indicate their degree of agreement on a 4-point Likert scale ranging from strongly agree to strongly disagree. Table 26 gives the degree of agreement for each item, and the means and standard deviations for the entire sample (N=155). It can be seen that the SRP was perceived to have been more effective in deepening participants' knowledge of science beyond what the school curriculum could offer (with 94% in agreement), and sharpening their scientific skills (85%). In terms of contributing to students' continuing interest and work in science, the program was perceived as less impactful, with all the means 3 and below. For three of the items, the rate of agreement was below 65%, with a mean of about 2.7. The three items were "SRP affirmed my interest in science research", "SRP strengthened my resolve to pursue science at university level" and "SRP made me surer that I want(ed) to pursue a career in science".

Table 26

Impact of the SRP – all cohorts

	#	%	M	SD
SRP further stimulated my interest in science.	128	82.5	3.01	.702
SRP affirmed my interest in science research.	99	63.9	2.75	.769
SRP deepened my knowledge beyond what the school curriculum could offer.	145	93.6	3.32	.674
SRP sharpened my scientific investigative skills.	131	84.6	3.08	.702
SRP exposed me to different career possibilities in science.	113	72.9	2.95	.759
Strengthened my resolve to pursue science at university level.	97	62.6	2.76	.830
SRP made me surer that I want(ed) to pursue a career in science.	85	54.8	2.68	.875
Overall the SRP influenced me to a great extent	122	78.7	2.86	.635

Was the picture similar for boys and girls? Table 27 presents the descriptive statistics.

Table 27

Impact of SRP by gender

	Male				Female			
	#	%	M	SD	#	%	M	SD
SRP further stimulated my interest in science.	89	80.2	2.97	.719	39	88.6	3.11	.655
SRP affirmed my interest in science research.	69	62.1	2.73	.774	30	68.2	2.80	.765
SRP deepened my knowledge beyond what the school curriculum could offer.	101	91	3.24	.716	44	100	3.52	.505*
SRP sharpened my scientific investigative skills.	94	84.7	3.07	.723	37	84.1	3.11	.655
SRP exposed me to different career possibilities in science.	77	69.3	2.88	.772	36	81.8	3.14	.702
Strengthened my resolve to pursue science at university level.	66	59.4	2.70	.848	31	70.4	2.91	.772
SRP made me surer that I want(ed) to pursue a career in science.	57	51.3	2.59	.878	28	63.7	2.89	.841
Overall the SRP influenced me to a great extent	87	78.4	2.86	.653	35	79.6	2.86	.594

$p < .05$

It appears that the SRP had a greater impact on girls than boys, based on mean score differences of their degree of agreement with the seven items. The girls' degree of agreement was higher than that of the boys for every single item. One hundred per cent of the girls (M=3.5) compared to 91% of boys (M=3.2) agreed that "SRP deepened my knowledge beyond what the school curriculum could offer". The difference between means was statistically significant at the $p<.05$ level ($F=5.586$, $df=1$, $p\leq .019$) Among the three items that showed the greatest difference was "SRP exposed me to different career possibilities in science". This could be one of the reasons for the difference in the next two items: "SRP strengthened my resolve to pursue science at university level" and

"SRP made me surer that I want(ed) to pursue a career in science". However, none of these differences was statistically significant.

When comparing the data across the cohorts, the perceptions of the younger participants appeared to be more positive. For instance, 68.5% of Cohort 1 students agreed that "SRP made me surer that I want to pursue a career in science", compared to only 46.1% of Cohort 2 and 36.7% of Cohort 3 students. The difference in means was statistically significant at the $p<.01$ level ($F=4.885$, $df=2$, $p\leq.009$). The trend for "SRP strengthened my resolve to pursue science at university level" was similar, climbing from 46.7% to 55.8% to 74% for Cohorts 3, 2 and 1 respectively. As Table 28 shows, the SRP appears to be perceived as more 'impactful' by the younger students in contributing to their continuing interest in science and planned involvement in the field. (ANOVAs for gender and cohort are in Appendices E5 and E6).

Table 28

Impact of SRP by cohort

	Cohort 1				Cohort 2				Cohort 3			
	#	%	M	SD	#	%	M	SD	#	%	M	SD
SRP further stimulated my interest in science.	66	90.4	3.12	.686	40	76.9	2.92	.682	22	73.3	2.90	.759
SRP affirmed my interest in science research.	50	68.5	2.81	.758	30	57.7	2.65	.789	19	63.4	2.77	.774
SRP deepened my knowledge beyond what the school curriculum could offer.	66	90.4	3.29	.716	50	96.1	3.38	.631	29	96.7	3.30	.651
SRP sharpened my scientific investigative skills.	64	87.7	3.14	.694	43	82.7	3.06	.698	24	80	3.00	.743
SRP exposed me to different career possibilities in science.	56	76.7	3.00	.764	36	69.2	2.88	.704	21	70	2.97	.850
Strengthened my resolve to pursue science at university level.	54	74.0	2.92	.812	29	55.8	2.65	.764	14	46.7	2.57	.935
SRP made me surer that I want(ed) to pursue a career in science.	50	68.5	2.90	.869	24	46.1	2.46	.803	11	36.7	2.50	.900**
Overall the SRP influenced me	59	80.8	2.86	.585	40	76.9	2.88	.704	23	76.7	2.86	.594

** $p<.01$

Since the SRP is a mentorship program, one way to gauge the impact of the program is by assessing the impact of the mentor since the goals and objectives were to be achieved mainly through the mentor. Six items pertaining to the impact of the mentor were given. Table 29 presents the descriptive statistics for the entire sample, and by gender. The only item that had fewer than 60% of students agreeing with it was my mentor "inspired me to consider a career in science research"; it also had the lowest mean of 2.67. The analysis by gender did not reveal significant differences in the way male and female students perceived the impact of their mentors, as none of the differences between boys and girls was statistically significant. It is, however, worth noting that, unlike the ratings for the impact of the SRP, the ratings awarded by girls for impact of the mentor were lower than those awarded by boys.

Table 29

Impact of Mentor all cohorts and by gender

	All cohorts				Male				Female			
My mentor	#	%	M	SD	#	%	M	SD	#	%	M	SD
a. taught me skills in scientific research	131	84.5	3.05	.694	93	83.8	3.04	.676	38	86.4	3.09	.741
b. exemplified the qualities of a scientist	121	78.1	3.03	.760	88	79.3	3.06	.749	33	75.0	2.93	.789
c. was passionate about his/her work	138	89.1	3.26	.694	100	90.1	3.30	.657	38	86.4	3.16	.776
d. cared for me as an individual	115	74.2	2.99	.840	81	72.9	3.00	.824	30	68.2	2.95	.888
e. was an excellent role model	111	71.6	2.92	.819	81	72.9	2.96	.801	34	77.3	2.79	.861
f. inspired me to consider a career in science research	89	57.4	2.67	.848	64	57.6	2.69	.810	25	56.8	2.61	.945

A comparison was made across the cohorts to see if perceptions of the impact of the program had changed in the course of 15 years. Judging by the descriptive statistics in Table 30, there is a discernible trend towards more positive perceptions for all the items. A one-way ANOVA showed that the differences in the means for two items "my mentor exemplified the qualities of a scientist" ($F=5.815$, $df=2$, $p \leq .004$) and "my mentor was passionate about his/her work" ($F=5.913$, $df=2$, $p \leq .003$) were statistically significant. Tukey's post-hoc showed that the difference was between Cohorts 2 and 3. The more positive perceptions of Cohort 1 students could have accounted for the percentage agreeing with "my mentor inspired me to consider a career in science research" rising quite dramatically from 50% for Cohort 2 and to 67.1% for Cohort 1. (ANOVAs by gender and cohort are in Appendices E7 and E8).

Table 30

Impact of mentor by cohort

	Cohort 1				Cohort 2				Cohort 3			
	#	%	M	SD	#	%	M	SD	#	%	M	SD
My mentor												
a. taught me skills in scientific research	66	90.4	3.18	.674	42	80.7	2.96	.713	23	76.6	2.90	.673
b. exemplified the qualities of a scientist	66	90.4	3.23	.698	35	67.3	2.79	.750	20	71.4	2.93	.813**
c. was passionate about his/her work	70	95.9	3.44	.623	43	82.7	3.02	.727	25	86.2	3.24	.689**
d. cared for me as an individual	58	79.5	3.12	.832	35	67.3	2.85	.894	22	75.8	2.90	.724
e. was an excellent role model	59	82.0	3.07	.775	34	65.4	2.77	.854	18	62.1	2.79	.819
f. inspired me to consider a career in science research	49	67.1	2.84	.764	26	50.0	2.50	.897	14	48.2	2.55	.910

** $p<.01$

Qualitative results

Another data source in the questionnaire that shed some light on participants' perceptions of the impact of the SRP on them was in the open-ended section where they were asked to write about the most and least valuable and most and least enjoyable aspect of the SRP.

If there was an aspect of the SRP that participants overwhelmingly agreed on, it was that the program "deepened my knowledge beyond what the school curriculum could offer", and "sharpened my scientific investigative skills", with 93.6% and 84.6% agreeing with these statements respectively. When asked about the "most valuable aspect of SRP", many students, especially from Cohort 1, wrote about "learning practical science skills that are merely taught in theory in school", "opportunities to experiment with equipment and materials outside of the school curriculum", "hands-on experience with technology and research procedures that are not available in the school lab" and "the opportunity to use proper research facilities and to design my own experiments with the tutelage of my mentor". A Cohort 1 female contrasted the teaching of science in school, and how she experienced science in the SRP. Describing laboratory experiences in school she wrote: "The scientific method is not well taught. Practical experiments require an almost mindless following of instructions. The reagents are all prepared for students. Observations and deductions can be made by rote. This gives the impression that science is a manufactured, generated out of thin air study." Of her SRP experience, she said that "if I had not been in the SRP, I would not have experienced a comprehensive study of the scientific process, which the SRP gave me, because it focused not just on the results, but also the process of achieving it. It has strengthened my interest in science, and my desire to pursue research as a career." Linked to this was another effect cited by many, especially the girls – that SRP boosted their confidence. A Cohort 2 female student said it was difficult to crystallize what she experienced into a single most valuable feature, because she found all of them valuable: "The early exposure to the scientific lab, being part of ongoing experiments, becoming confident in lab procedures, also early introduction to public speaking and presenting our work both verbally and in writing; interacting socially with peers with similar and sometimes very different outlooks, forming new friendships..." A Cohort 3 female attributed her involvement in science today to her mentors - the confidence they had in her enabled her to overcome her self-doubt, and nudged her towards pursuing her dream of a career in science.

Another valuable aspect of the program was the exposure participants had to the "life of a real scientist" and "the real life of a scientist", and getting to know one up close and personal and witness first hand how he/she worked gave participants a better idea of what the life of a scientist was. As one student put it: "I got to learn that research in science is difficult and requires much hard work and doggedness; not the impression that many school kids have of scientists where there is a mystique and glamour to doing cutting edge work." Another student offered this insight: I "realized that tons of research has been generated by thousands of researchers out there, [and] much of it is never read. It is a very humbling experience. I also witnessed the lab politics that occurred among the various labs..." SRP helped another student "appreciate the efforts and commitment that scientists have for their work", and enabled him to "catch a glimpse of what life in academia was like", deciding that academia was not for him.

It is interesting that several students who had made up their minds not to go into science research or to leave science altogether said that the most valuable part of their SRP experience was to discover that they were not cut out for science/science research. One student put it this way: "I realized scientific research (lab work) is not universally interactive most of the time, you spend a lot of time absorbed in your work like reading a book the whole day - not for me! [It] made me acutely aware that science research is not for me". Others who opted out wrote in a similar vein: "Knowing/learning that research is just not my idea of a suitable career for me"; "I understood that I was not as interested in experimental science as I thought I was" and "I realized that I may not be well-suited for science research". For yet others, SRP helped them discover the area of science to pursue. One Cohort 3 male wrote: "I guess I figured out that I didn't want to do chemistry as a major in college". He went on to do computer science.

SRP was also valued by participants for the opportunities it provided for like-minded budding scientists to meet, and share their interests and passion. Cohorts 2 and 3 students also wrote about the friendships forged with student-scientists from other countries, as there was an overseas component, when students from the Asia-Pacific region were invited for the three-week stay-in phase of the program. Indeed, the mandatory residential program seemed to be one of the most "enjoyable aspects of the SRP" for many students in these two cohorts. The stay on campus meant they need not commute to the university for meetings with mentors. It also gave them the opportunity to observe peers engaging in research work, and exposed them to other areas of science that students were working on. They also appreciated the social program which promoted social interaction. Those who disliked the mandatory stay were those whose mentors were away on vacation or whose labs were closed, and they saw no point in staying on campus "when there was no work to do".

Based on the views of Cohort 1 students, it appears that their perceptions of the SRP were somewhat affected by the fact that there was no residential component for them. This was because of the outbreak of Severe Acute Respiratory Syndrome (SARS) in Singapore then. Cohort 1 students found the attachment during school term very difficult due to clashes in schedule. One student said she had to struggle preparing for her final exam and writing the final report for SRP. School work interfered with full-time commitment to SRP, and the timeframe was too short and tight, and made it hard to accommodate setbacks in experiments. Others complained that the duration of the attachment was too short, and "so research was not really in depth and results also not very conclusive". Apparently, the commute to and from school and the university lab posed serious challenges for many of them, and it made them even "more negative" about the "long hours waiting for results in the lab" which many cited as the "least valuable and least enjoyable" aspect of the program. From the data, it appears that for Cohort 1 students, the logistics of the program seemed to have weakened the impact SRP had on them.

Summary of Question #2 findings

Across the cohorts SRP participants perceived science as hard work, and they felt that to be a successful scientist, one needed to have the curiosity to ask questions, and the perspicacity to find the answers to one's questions, and perseverance to stay the course in one's quest. On the impact of the SRP, it appears that the program was more successful in enhancing students' scientific and investigative skills than it was in sustaining or affirming their interest in science research. While participants were almost unanimous in their agreement that the SRP deepened their science knowledge beyond what the school curriculum offered, they were more ambivalent about the impact their mentors had on them. Cohorts 2 and 3 participants appreciated the opportunity to interact with peers with similar scientific interests, especially during the period of the 3-week campus stay. Cohort 1 students, on the other hand, did not get to experience the residential component due to the SARS outbreak. One of their main complaints was the conflict of SRP and school schedules, and the time-consuming commute to the university.

Question #3 Results

The focus of the third research question was on the role of teachers and mentors in nurturing gifted science students' interest in science. The question was: What types of teachers and mentors do gifted science students feel have contributed to the development of their high interest in science? Is there a significant difference in the perceptions of male and female students? Data to answer these questions were drawn from different sections of the questionnaire.

Students were given a list of fifteen characteristics of effective teachers. This list was drawn up based on the literature on effective teachers of the gifted as well as discussion with students who participated in focus groups during the pilot of the survey questionnaire. In this study, respondents were asked to choose in rank order *only* the top three most essential traits of effective (science/math) teachers, with '1' being the most essential.

Descriptive statistics for the whole group, by cohort and by gender are presented in Tables 31, 32 and 33. The mean scores reflect the general agreement among students on traits associated with effective math/science teachers.

Table 31

Essential qualities of effective teachers - all cohorts

	#	M^	SD
Deep content knowledge	34	1.97	.758
Curious about the world	9	2.11	.782
Genuine interest in the student as an individual	73	**1.58**	.762
Willingness to discuss topic beyond syllabus	67	2.04	.787
Very clear in his/her teaching	68	**1.82**	.809
Sense of humor	17	2.59	.795
Asks good questions	8	2.38	.744
Discusses applications to real life	35	2.37	1.140
Passion for the subject	71	**1.85**	.873
Models the habits of mind of a scientist	5	2.60	.548
Prepares students well for national exams	13	2.54	.660
Available for consultation after class	13	2.38	.650
Prepares lessons well	28	2.07	.813
Open to divergent ideas	10	2.60	.699
Makes connections to other subjects	8	2.75	.463

^ Each trait is assigned a rank of 1, 2 or 3 with '1' being the most essential. The sum of the rank assigned by all respondents divided by the number of respondents is the mean.

From Table 31, it can be seen that the three most essential qualities are "Genuine interest in the student as an individual" (M=1.58), "very clear in his teaching" (M=1.82) and "passion for the subject" (M=1.85). The means show the degree of importance placed on each trait, the lower the mean, the more important the trait. In terms of frequency of times each trait is chosen by respondents, regardless of the rank order, the three most cited items are "Genuine interest in the student as an individual" (73); passion for the subject"(71) and "very clear in his teaching" (68).

An analysis by cohort and gender, however, showed that the order was different for each cohort, and for boys and girls. Table 32 presents the frequencies by cohort.

Table 32

Essential qualities of effective teachers by cohort

	Cohort 1 (N=73)		Cohort 2 (N=52)		Cohort 3 (N=27)	
	#	%	#	%	#	%
Deep content knowledge	16	21.9	13	25.0	5	18.5
Curious about the world	4	5.5	4	7.7	1	3.7
Genuine interest in the student as an individual	33	*45.2*	28	**53.8**	12	*44.4*
Willingness to discuss topic beyond syllabus	32	43.8	24	*46.2*	11	*40.7*
Very clear in his/her teaching	33	*45.2*	26	50.0	9	33.3
Sense of humor	11	15.1	4	7.7	2	7.4
Asks good questions	2	2.7	5	9.6	1	3.7
Discusses applications to real life	11	15.1	15	28.8	9	33.3
Passion for the subject	24	**46.6**	21	40.4	16	**59.2**
Models the habits of mind of a scientist	2	2.7	2	3.8	1	3.7
Prepares students well for national exams	11	15.1	1	1.9	1	3.7
Available for consultation after class	8	11	3	5.8	2	7.4
Prepares lessons well	13	17.8	10	19.2	5	18.5
Open to divergent ideas	5	6.8	1	1.9	4	14.8
Makes connections to other subjects	6	8.2	0	0	2	7.4

To the Cohort 1 students "passion for the subject" (46.6%), "genuine interest in the individual" and "very clear teaching" (45.2%) were close to equally important. To the Cohort 2 students, the three most important were "genuine interest in the individual"

(53.8%), "very clear teaching" (50.0%), and "willingness to discuss topic beyond syllabus" (46.2%). "Clear in teaching" was not as important to the Cohort 3 students, who picked as their top three traits "passion for the subject" (59.2%), followed by "genuine interest in the individual" (44.4%) and "willingness to discuss topic beyond the syllabus" (40.7%). Consistently, "genuine interest in student as individual" was cited. This was also the case when the analysis was done by gender. See Table 33.

Table 33

Essential qualities of effective teachers by gender

	Male (N=108)				Female (N=44)			
	#	%	M	SD	#	%	M	SD
Deep content knowledge	24	22.2	2.04	.751	10	22.7	1.80	.789
Curious about the world	7	6.5	2.14	.690	2	4.5	2.00	1.414
Genuine interest in the student as an individual	51	**47.2**	1.55	.730	22	**50.0**	1.64	.848
Willingness to discuss topic beyond syllabus	46	***42.5***	2.04	.759	21	*47.7*	2.05	.865
Very clear in his/her teaching	44	40.7	1.75	.811	24	**54.5**	1.96	.806
Sense of humor	16	14.8	2.56	.814	1	2.3	3.00	.
Asks good questions	6	5.6	2.33	.816	2	4.5	2.50	.707
Discusses applications to real life	26	24.0	2.46	1.240	9	20.5	2.11	.782
Passion for the subject	52	***46.8***	1.83	.901	19	43.2	1.89	.809
Models the habits of mind of a scientist	3	2.8	2.33	.577	2	4.5	3.00	.000
Prepares students well for national exams	12	11.1	2.58	.669	1	2.3	2.00	.
Available for consultation after class	6	5.6	2.17	.753	7	15.9	2.57	.535
Prepares lessons well	21	19.4	2.14	.793	7	15.9	1.86	.900
Open to divergent ideas	7	6.5	2.71	.756	3	6.8	2.33	.577
Makes connections to other subjects	4	3.7	2.75	.500	4	9.1	2.75	.500

One-way ANOVAs were performed for gender and cohort: none of the differences were statistically significant. Nevertheless, it was interesting to note that it is more important to boys (M=1.55) than girls (M=1.64) that teachers show a genuine interest in students as individuals. A higher percentage of girls chose "clear in teaching" (54.5%) than "genuine interest in student as individual" (50.0%). More girls (16%) than boys (5.4%) picked "available for consultation after class" as important. "Sense of humor" was picked by 15% of boys and 2% of girls. Similarly, boys (11.1%) seemed more concerned than girls (2.3%) that teachers "prepare students well for national exams." Given the importance placed on high-stakes exams, it is surprising that overall, only 8% of students thought it was essential that teachers deliberately prepare them.

In another section of the questionnaire, students had to indicate the "most important person" in their talent development journey. Table 34 shows the 'nominations' of the students.

Table 34

Nominations of most important person by cohort and gender

Cohort	Self		Teacher		Parents		Others	
	#	%	#	%	#	%	#	%
Cohort 1 (N=73)	36	49.3	20	27.3	8	10.9	9	12.3
Cohort 2 (N=49)	20	40.8	18	36.7	9	18.3	2	4.1
Cohort 3 (N=29)	10	34.4	9	31.0	9	31.0	1	3.4
Gender	#	%	#	%	#	%	#	%
Male (N=108)	52	48.1	30	27.8	19	17.6	7	6.5
Female (N=43)	14	32.5	17	39.5	7	16.2	5	11.6

Several observations can be made. Firstly, analysis by cohort revealed that students thought the 'self' was most important in their talent development journey, and the role of the self seemed to be increasing in importance, with 50% Cohort 1 nominating "self", followed by 41% of Cohort 2, and 34% of Cohort 3. Secondly, SRP students felt that their teachers played a more important role than their parents in helping to develop their talent. Thirdly, more girls than boys perceived their teachers as "the most important person". Finally, teachers' role seemed to be diminishing in importance, (in relation to the importance of the 'self'), with Cohort 2 citing the strongest percentage response, followed by Cohort 3 and then Cohort 1. That teachers played a more important role than parents was also reflected in student ratings on 15 items pertaining to factors that contributed to their early interest in science. (cf Table 18).

Qualitative results

The quantitative data were corroborated by students' descriptions of teachers who had left indelible impressions on them. One section of the questionnaire required students to nominate a (science/math) teacher who had left a deep impression, and to describe the qualities of the nominated teacher. This section provides the best insights on students' perceptions of the type of teachers who are influential in students' development in the sciences. Table 35 shows the gender of the teachers nominated and the level they taught. There is a discernible trend here: more and more male teachers were nominated across cohorts, and girls tended to nominate their junior college (JC [grades 11& 12]) teachers rather than their secondary school (Grades 7 to 10) teachers.

Table 35

Gender and grade of teachers nominated by students

		JC		Secondary		Primary	
		M	F	M	F	M	F
Cohort1							
	Boys (N=48)	12	6	18	12	0	0
	Girls (N=18)	6	5	0	7	0	0
Cohort 2							
	Boys (N=28)	7	4	13	4	0	0
	Girls (N=15)	5	3	2	5	0	0
Cohort 3							
	Boys (N=16)	2	5	1	7	1	0
	Girls (N=4)	1	1	1	1	0	0

One theme that emerged from the comments, especially from the Cohort 1 students, was teaching effectiveness. A male student said his JC teacher was able to "make abstract concepts in chemistry easier to understand by using analogies". Another said his secondary chemistry teacher "taught it in a very analytical and concise manner and this made it very easy for us to understand the concepts". "He was able to teach physics in an absolutely interesting way despite the fact that he rarely made use of teaching and visual aids", a boy said of his secondary physics teacher. Many students alluded to the "clarity" of teaching. A boy said of his Grade 7 science teacher: "He teaches with exceptional clarity and has the ability to engage the interest of his students in a way that I have yet to experience since." A male student said his secondary chemistry teacher was "very clear in her teaching." Another said his teacher's "lively way of teaching ensured that we remembered what she taught even after class" was over. A boy described his teacher's lesson as "very clear and well organized… he would always begin each lesson with an interesting anecdote to engage our interest". Another boy said of this same teacher: "He would prepare a mini quiz for every lesson...they were very effective in stimulating our thoughts". Yet another commented on this same teacher: "His lessons are invariably well-planned; he cultivated in us an interest to find out more about science, and since he taught the basics so well, we could delve deeper into the subject."

Students also appreciated teachers who exposed them to relevant extra curricular programs. A girl said of her secondary biology teacher: "She always encouraged us to attend talks by external speakers. She recommended me for the Science Mentorship Program (for 9th grade students) and that was what really kick-started my interest in research." A girl said of her JC biology teacher: "He's always encouraging me to go for biology talks and workshops, and would share any new and interesting scientific discoveries with us." A boy from Cohort 2 said his lower secondary (grades 7 & 8) science teacher "always encouraged me to go for those science fairs as he knew that I expressed an interest in science." Yet another said of his secondary biology teacher: "She motivated and encouraged students to participate actively in research". His schoolmate commented on this same teacher: "It was she who first introduced me and gave me the chance to do research, and in doing so, sparked my interest. I am deeply indebted to her." His remarks were echoed by another: "She exposed me to the world of research, and increased my interest in science". Another schoolmate added: "She is constantly encouraging us to pursue projects outside the syllabus, and she would help us with the projects, experimental processes, and encourage active discussion and analysis of the results."   A male from Cohort 3 wrote that his secondary biology teacher "was very encouraging of independent learning and supportive of project work and research". This teacher taught in the same school as the biology teacher mentioned by several boys from Cohort 1, a school known for its culture of research.

The open-ended responses corroborated the quantitative finding that students respect teachers with deep content knowledge, and liked them to discuss topics beyond the syllabus, and not confine lessons to preparation for national exams. Comments like "very knowledgeable" and "'deep content knowledge and experience", "extremely well-read" were common across the cohorts. A Cohort 1 male wrote of his chemistry teacher: "He has in-depth knowledge of the subject…and he has the ability to inspire in students a sense of wonder about chemistry and its importance to everyday life." While a few students from Cohort 1 specifically mentioned teachers who "prepared excellent notes, and prepared us well for the exams", a couple of students from Cohorts 2 and 3 wrote that they were thankful their teachers "were *not* exam-oriented and were not obsessed with producing A's only." A boy from Cohort 2 said although his teacher was young and inexperienced, "he tried to let students see the beauty in the subject, teaching passionately, as opposed to teaching for the grades only". Another said his JC math teacher was not only passionate about math, but "willing to share his passion with his students". This same math teacher was credited by another student "for encouraging me to pursue math/physics. If I had to name a person who inspired me to do science, it would have to be him." An observant Cohort 2 student wrote of his JC math teacher: "He had an avid interest in the subject, and was thrilled whenever students asked questions beyond the text. At the same time he was very patient when entertaining questions of 'slower' students." A few students mentioned teachers who were not only "not put off by students' questions but took the pains to do the research in order to answer them". These students were inspired by their teachers' continuing pursuit of knowledge. A Cohort 3 student who is now a teacher said "I loved her lessons and she spurred my interest in biology." Five of the 20 Cohort 3 respondents alluded to their teachers' willingness "to go beyond the syllabus" and this "inspired curiosity" and promoted "genuine understanding" of the subject as the 'O' Level exams "emphasized rote learning." A Cohort 1 boy described his secondary biology teacher in this way: "His lessons are full of energy and dynamics, and seem to flow rather than be stifled by having a fixed, artificial, series of deadlines for each topic. Real life scenarios are brought in spontaneously – there's no unnecessary preamble about bringing a real-life example into the classroom because there is no clear distinction between the world and the classroom." Acknowledging that such a 'teaching style' might not appeal to some students, another boy wrote of this same teacher: "He's highly animated, highly engaging, and his lessons are free-flow non-curriculum based; not really an effective 'syllabus teacher', but excellent as an educator."

Passion for the subject was also often mentioned. Comments like "his obvious passion for the subject", "he is really passionate about physics" were common across the three cohorts. A Cohort 2 student wrote that her JC teacher "had a contagious passion for physics". A girl from Cohort 1 said her teacher "is passionate about her subject and her students". It is noteworthy that students made a distinction between passion for the subject and passion for the students. As one Cohort 1 girl succinctly put it: "He is very passionate about biology and about educating young people". A Cohort 2 boy said of his lower secondary math teacher: "Most important of all, she showed a passion for her students and the subject." A few students also distinguished between a teacher who is "dedicated to his job", and "dedicated to his students". A girl from Cohort 2 who is currently doing a course in medicine wrote of her secondary biology teacher: "She was inspiring in her passion for her subject, gave us a solid grounding in the foundation for biology, taught us how to do projects independently, and tried to stretch our potential to the fullest. Even now, the memory of her teaching continues to inspire me and I am very much indebted to her for it." Two other Cohort 2 girls also mentioned how they were inspired by the passion of their physics teachers. A male student from Cohort 3 commented on his JC physics teacher: "Although she was fresh from NIE (National Institute of Education), she was very passionate about the subject and about teaching".

As expected, genuine care for students (rated as "most essential trait of effective teachers") was a recurring theme. "She cares deeply about her students", "she is an extremely dedicated and devoted teacher who cares for her students academically and as individuals" were comments made by male and female students. A girl said her teacher "was very caring and genuinely interested in us; we can find her when we have problems and she will always help us." Another girl said of her JC teacher: "He teaches us more than chemistry; he is also concerned about our well-being." A Cohort 2 boy sums it up thus when he wrote of his lower secondary science teacher "who demonstrated a genuine concern for us as individuals, and went to great length to make us feel part of a big family…taught us to do the right thing, to be better people. And perhaps because of this friendship that was nurtured, I took more pains with science, so as not to disappoint my teachers who have become friends". Several students from Cohort 3 reminisced about their lower secondary teachers (who taught them more than 15 years ago) "who cared for students". A male student wrote of his JC teacher: "She was interested in my life." Yet another said his JC teacher "believed in my ability to cope with biology 'S' paper; she recommended to the committee to let me continue with 'S' biology (I wasn't doing well in the other subjects); so I ended up with one 'S' paper, and got a distinction for that."

Two male students from Cohort 2 also wrote about teachers who believed in them, and advocated on their behalf. One said his JC teacher believed he ought to participate in the SRP and wrote an appeal letter to the SRP committee when his application was rejected. Another said his JC biology teacher "actively encouraged my participation in the SRP. She was strongly behind my decision to go into research, and wrote many testimonials to support my university applications." As can be seen, teachers who recognized the talent in their students, and actively encouraged them were both appreciated and remembered.

To summarize, teachers clearly played an important role in their students' development. It is remarkable that over 80% of respondents completed this section of the questionnaire, which required relatively more time and effort than the forced-choice sections. One student summed it up thus: "Teachers are so important...how they lead a class...push the class to explore...and are open to discussions with the class..." Although none of the students mentioned teachers as role models, they acknowledged admiration of teachers who were passionate about what they were doing, demonstrated the continuing quest for learning, sparked curiosity, and were enthusiastic to share their love for what they were teaching. Most important of all, students appreciated teachers who were interested in them as individuals, and cared for their development not only in the academic realm, but in all other aspects as well. That the Cohort 3 students can and do write so vividly about their teachers' impact says much about the powerful role and lasting influence of teachers on their young charges' development.

Traits of effective mentors

What type of mentors do SRP participants feel have contributed to their interest in science? In the questionnaire, students were given a list of ten traits of effective mentors, and asked to rank them, citing the three most essential characteristics. This list was based on discussion with students during the pilot phase of the questionnaire, as well as literature on effective mentors. Table 36 shows the descriptive statistics for all the cohorts, as well as the frequencies, by cohort and by gender.

The descriptive statistics show that the characteristic most valued by students is "Genuine interest in mentee as an individual", with the lowest mean of 1.52, meaning that the majority of students picked this as the most important trait. However, in absolute terms, "Knows when to help and when to let mentee work independently" and "Creates opportunities to give mentee more exposure in the field" garnered the greatest number of responses, with 81 each.

Analyses were done by cohort, and by gender. The top three traits were chosen by all three cohorts, although for Cohort 3 students, "passion for the subject" was a joint third with "creates opportunities to give mentee more exposure". The greatest number of Cohort 3 students, incidentally, also chose "passion for the subject" as an essential trait of effective teachers.

Table 36

Essential qualities of effective mentors

	All Cohorts (N=155)			Cohort 1 (N=73)		Cohort 2 (N=52)		Cohort 3 (N=30)		Male (N=111)		Female (N=44)	
	#	M	SD	#	%	#	%	#	%	#	%	#	%
Well versed in his/her field	32	1.91	.777	20	27.4	7	13.5	5	16.7	22	19.8	10	22.7
Genuine interest in mentee as an individual	79	1.52	.814	34	**46.6**	29	**55.8**	16	**53.3**	60	**54.1**	19	**43.2**
Willingness to discuss his/her research with mentee	49	1.94	.775	24	32.9	17	32.7	8	26.7	31	27.9	18	40.9
Helps mentee take risks	10	2.10	.876	7	9.6	2	3.8	1	3.3	8	7.2	2	4.5*
Knows when to help and when to let mentee work independently	81	2.22	.725	35	**47.9**	29	**55.8**	17	**56.7**	62	**55.9**	19	**43.2**
Passion for the subject	56	1.86	.819	22	30.1	20	38.5	14	**46.7**	43	38.7	13	29.5
Creates opportunities to give mentee more exposure in the field	81	2.12	.812	38	**52.1**	29	**55.8**	14	**46.7**	49	**44.1**	32	**72.7**
Open to divergent ideas	20	2.50	.688	12	16.4	3	5.8	5	16.7	18	16.2	2	4.5
Plans the program according to needs of mentee	34	2.12	.729	12	16.4	14	26.9	8	26.7	25	22.5	9	20.5
transmits attitudes and values of experts in the field	19	2.37	.684	11	15.1	6	11.5	2	6.7	13	12.6	5	11.4

*p<.05

While males and females picked the same three most essential characteristics, it was noted that more girls (72.7%) than boys (44.1%) chose "Creates opportunities to give mentee more exposure in the field". More boys (54.1%) than girls (43.2%), on the other hand, chose "Genuine interest in mentee as an individual". This is the reverse of the pattern for teachers where more girls than boys picked that trait. More boys than girls picked "Knows when to help and when to let mentee work independently". One-way ANOVAs showed that none of these differences were statistically significant. The one item that was statistically significant was "Helps mentee take risks" ($F(6.245)$, $df=1$; $p \leq .037$), with more boys than girls choosing this as an essential trait.

There was no specific open-ended question on effective mentors, but a good number of the students wrote about their mentors in the open-ended sections which asked them what was most and least valuable about their SRP experience, another reflection of the important role of mentors in the SRP participants' eyes. The observations reported here are culled from this section, and "Other comments".

Generally, the positive comments about the mentors had to do with their expertise, and their status. One student said the most valuable aspect of his SRP experience was "getting to work with a fulltime professor", and another said it was the "opportunity to work with someone much more knowledgeable than myself". One girl mentioned she was extremely fortunate to have the opportunity to discuss her scientific views "with my mentor who is an expert in the field." The Cohort 1 students whose SRP experience was most recent mentioned the value of mentors' guidance, and teaching. A male student said his greatest takeaway was the "close working relationship built with a superb mentor." A girl said she really enjoyed the "grueling hours in the lab thinking about, and discussing ideas with my mentor and the lab assistants". It was evident that students enjoyed the "intellectual fodder" that mentors provided.

Many also reported that they enjoyed the interaction and scientific discussions with their mentors. The Cohort 3 students seemed especially appreciative of the opportunities to "talk to mentors" about science and about life in science. A few students specifically alluded to the benefit of "getting to design my own experiment under the tutelage of my mentor", a clear reflection that they preferred mentors who knew when to allow mentees to work independently and when to offer guidance and help. A Cohort 1 student expressed it this way: "I was able to do the research I want, and expand on it with little spoon-feeding from my mentor." The encouragement of mentors and the laboratory assistants was also mentioned. One female student said the mentoring "boosted my self-confidence". A male student from Cohort 2 specifically mentioned his two mentors who were "caring, and trusted me, a normal person (who is not gifted and have no resources), to do research work". A female from Cohort 2 said she had such a wonderful relationship with her mentors that they still keep in touch today! Interestingly, a couple of students mentioned that they had a wonderful working relationship with their student-mentors. One, however, also bemoaned the fact that this was because he had little access to and direct contact with his "professional" mentor.

The negative aspects of the mentors had to do mainly with inaccessibility, the "poor attitudes" of mentors and their lack of understanding of their mentees. One

Cohort 1 girl did not mince her words: "My mentors underestimated us, refusing to let us delve into the subject any deeper. For SRP, my mentor practically did the whole project for me, and he changed the topic because he thought I was too young. I think the mentors should give us more credit." A Cohort 1 boy was no less direct: "I had a discouraging mentor, condescending attitude towards a student who he felt was unworthy because [he was] not yet university level and hence, should be doing nothing besides reading books". Another Cohort 1 student made an oblique reference to his mentor's lack of trust in him thus: [The least valuable part about SRP] was watching my mentor do all the experiments without him involving me."

On the other hand, other students wrote about the problem of the mentor's overestimation of their ability. The following quote about the least valuable aspect of SRP encapsulates the less than ideal situation in respect to overestimation: "...getting a project which was much too difficult for me to understand and carry out active research, and the [mentor's] lack of understanding that the technicalities were way beyond my abilities" (a Cohort 1 male student). This basic understanding of the mentee's capabilities was necessary if mentors were to be able to "know when to help and when to let the mentee work independently". It also required a level of trust in the mentee's abilities.

Two students from Cohort 2 wrote of their mentors: "I did not really get exposed to [subject] which was what I had hoped. My mentor was half-hearted." Another girl said: "My mentor...I hardly interacted with him and he expressed little if no interest in my work. I had to write the research report all by myself with no help from him at all." A boy complained about his mentor's "insincere attitude", while another wrote: “My mentor never remembered my name, nor the purpose of my weekly visits to him!” A girl lamented the “lack of one-to-one mentoring”, while yet another said the least enjoyable aspect of her SRP experience was “being left completely unguided, sometimes, especially during the initial part of the project.” Although several Cohort 3 students said they could not remember any “bad things since it has been many years”, the few who had unpleasant memories still recalled them with vividness. One wrote of his mentor: “…the project was merely presented to me and none of the background had been properly researched by the mentor, so the project was ultimately useless. The question simply was not a useful one.” Another who had otherwise positive views about the SRP said the least valuable part was “not being able to discuss research in depth with my supervisor as he was very busy”. One respondent said the least valuable aspect was “my interaction with my mentors, which frankly put me off research for quite a while.”

To sum up, the students took issue with mentors who did not care for them – indeed, according to the students, the mentors did not care about the mentoring either. That these negative memories were brought to the fore in the open-ended section of the questionnaire which did not focus on mentors showed how important it was to the students that mentors exemplified the essential characteristics of “genuine interest in mentee as an individual”, and “ know when to help and when to let mentee work independently”. Their admiration of their mentors’ expertise and experience reflects the importance accorded to the trait “well versed in the field”. (M=1.91).

Summary of Question #3 findings

Both male and female students attached great importance to the trait "genuine interest in student as individual" and most highly valued this trait in both their teachers and mentors. Across cohorts though, there were some differences in the way students ranked the essential traits of teachers and mentors. Cohorts 1 and 3 picked "passion for the subject" as one of the three essential traits of effective teachers, while Cohorts 1 and 2 students (who are still in school/college) picked "very clear in their teaching". "Willingness to discuss topics beyond the syllabus" was not as important to Cohort 1 students, compared to Cohorts 2 and 3. Regardless of the ranking, all three cohorts perceived their teacher's influence as greater than that of their parents on their talent development process. All three cohorts of students, both male and female, picked the same top three essential traits of mentors, though not necessarily in the same order. The major complaint they had about their mentors was inaccessibility, negative attitudes, and lack of understanding of their mentees.

Question #4 Results

The fourth research question sought to find out if SRP participants continued to enroll in science courses at university, and pursue careers in science after graduation. As survey respondents were at different stages of their academic and career pursuits, the findings are reported separately, by cohort. Comparisons across cohorts, where appropriate, were made.

Cohort 1 students indicated their intentions to enroll in science courses when they are at university. Of the 72 who answered this item, 10 (13.9%) would like to opt out of science. Of these 10, only one of them is a girl; the other 17 girls would like to remain in science. However, when students were asked if they would like to have a career in science, the figures dropped slightly. Of the 72 respondents, 58 (80.6%) gave an affirmative answer. This means that among those who intend to enroll in science courses, they *already* have plans to go into non-science careers, like business and finance. Among those who plan to opt out of a science career, two are girls. For those who plan to stay in science, the majority of them hope to major in biology/life sciences (15), medicine (10), biomedical (4), and engineering (15). Very few have plans to major in physics (4), chemistry (1), and math (2). Two plan to go into computer science.

Of the 52 Cohort 2 students, 48 (92.3%) are currently enrolled in science courses, and of these, 45 plan to go into science careers. (The percentage is probably higher as more than half of those who failed to return their surveys are enrolled in science courses.) Of the 19 female respondents, only one plans to leave science. The fields these students plan to enter tend to be in the applied areas like medicine (17), biology/life sciences (6) and engineering (16). Like their younger counterparts, only a few plan to major in physics (1), chemistry (3), math (2), and computer science (2). Tables 37 and 38 reflect these findings.

Table 37

Students in science or non science course and career by cohort

	Cohort 1		Cohort 2		Cohort 3		Total	
Course	#	%	#	%	#	%	#	%
Science	62	86.1	48	92.3	26	86.7	136	88.3
Non Science	10	13.9	4	7.7	4	13.3	18	11.7
Career								
Science	58	80.6	45	86.5	21	70.0	124	80.5
Non Science	14	19.4	7	13.5	9	30.0	130	19.5

Table 38

Frequencies of majors - all cohorts^

	Cohort 1	Cohort 2	Cohort 3
Biology (including life science)	15	6	2
Medicine	10	17	14
Biomed	4	0	0
Pharmacology	2	0	0
Engineering	6	6	1
aeronautical	1	2	0
bioengineering	3	2	1
neuroelectrical engineering	1	0	1
material science	2	1	0
mechanical engineering	2	4	0
Chemical engineering	0	1	1
Math	2	2	2
Chemistry	1	3	0
Physics	4	1	0
Computer science	2	2	4
Business or law or finance or accounting or architecture	3	3	4
History of science	0	1	**0**

^ not all students indicated majors or intended majors

Both Cohorts 1 and 2 students seemed to be very much aware of the blurring distinctions among the sciences, and a good number wrote in the open-ended sections, about the interdisciplinary nature of the emerging fields, and how they plan to extend beyond their 'favorite' area in order to compete for careers in the new fields.

The Cohort 3 respondents are currently in the work force. Of the 30 of them, 26 of them majored in science at university but only 21 of them are now in science or science-related careers. Of the 21 in science, two-thirds are in medicine or medical-related fields (e.g. histopathology). Three are in engineering, two in academia, one in instructional technology, and one is a doctoral candidate in computer science. (See Table 39). Besides the two in academia, only three others, all in the medical and related fields, reported being involved in research work.

Table 39

Occupations of Cohort 3 by gender

	Male	Female
Science		
Medical officer & related	10	4
Engineer	3	0
Academia (math)	2	0
IT- related	1	0
Computer science	1	0
Non Science		
Legal	1	0
Finance	1	0
Architecture	1	0
Foreign Service	1	0
Management	1	1
Teaching	2	0
Homemaker	0	1

Analysis by gender revealed that contrary to conventional belief, more females than males intended to or were enrolled in science courses, and planned to pursue careers in science. However, while 100% of males planned to work full-time even when they had children, only 81.4 % of females had such plans. Table 40 reflects these findings.

Table 40

Enrolment in science and career plans by cohort and gender

	Cohort 1		Cohort 2		Cohort 3		Total	
	N=54		N=33		N=24		N=111	
Male	#	%	#	%	#	%	#	%
Science Course	45	83.3	31	93.9	20	83.3	96	86.5
Science Career	42	77.8	27	81.8	17	70.8	86	77.5
Work full time	50	100	33	100	23	100	106	100.0
	(N=50)		(N=33)		(N=23)			
Female	N= 18		N=19		N=6		N=43	
Science Course	17	94.4	17	89.5	6	100.0	40	93.2
Science Career	16	88.9	18^	94.7	4	66.7	38	88.4
Work full time	17	94.4	18	94.7	1 (N=5)	20.0	35	81.4

^ 1 student perceived psychology as a non-science course but psychologist as a science career

Six females (of 42) said that careers would take a back seat when they have children. Of the six, there is one each from Cohorts 1 and 2, and four from Cohort 3. This is probably because the younger participants have not reached "the proverbial bridge" where they would have to make a choice between career and children. Two quotes from the Cohort 3 females were telling:

"Each person has a niche in this world and I'm happy in mine right now. Raising a child is as much an art as it is a science. My training in school (though intangibly) definitely contributes to the way my children will be raised" (A fulltime mother of 1). "It is my dream to be a fulltime mom and pick up medicine again later on - my kids are only young once" (A Cohort 3 anesthetist).

Those who were enrolled in science courses were asked to indicate their extent of agreement with a number of statements pertaining to their course-taking decisions. This was to ascertain the variables that were factored into their course-taking decisions, and to ascertain if their current experience at university would influence their career decisions.

Table 41 shows the extent of agreement for males and females by cohort. As is evident from the table, the students are enjoying/enjoyed their science classes at university, and aspire to make contributions in the field of science. Although only 74% agreed that they had a "good mentor who supports and encourages" them, an overwhelming 90% plan to have a career in science. Like the Cohort 1 students who have already made plans to leave science, this can perhaps be seen as another indicator that *other* life factors are at play in their career-making decisions, and these may not have much to do with their experience at university or with their mentors.

This also seemed to be true of the Cohort 3 participants. Although 100% of the male participants reported that they enjoyed science classes, only 85% had stayed on in a science career. This percentage was much higher than the percentage (55%) reporting that they had a good mentor who supported and encouraged them.

Table 41

Perceptions and plans of students' in science courses for Cohorts 2 & 3 by gender

	Enjoy science classes at university		Intend to pursue a career in science		Have a good mentor who supports and encourages me		Have been awarded a scholarship to pursue science		Had very good grades for science at A Levels		Hope to make a contribution in science	
Cohort 2	#	%	#	%	#	%	#	%	#	%	#	%
Male (N=29)	27	96.4	26	89.7	15 (N=27)	55.6	20 (N=28)	71.4	22	75.9	27	96.4
Female (N=16)	16	100.0	15	93.8	10 (N=15)	66.7	11 (N=15)	73.3	13	81.3	15	93.8
Cohort 3												
Male (N=20)	20	100.0	-	-	11	55.0	6	30.0	18	90.0	17	85.0
Female (N=6)	4	66.7	-	-	2	33.3	0	0	3	50.0	4	66.7

The comparison between Cohorts 2 and 3 showed that the percentage of participants who had been awarded scholarships to pursue science courses had more than doubled, from 30% to slightly over 70%. A Cohort 3 respondent said he had opted out of science because of the "prohibitive cost" of getting a science degree. He wrote: "There were not many scholarships for science majors, and the few available were linked to engineering. Given the long duration of getting a science doctorate and hence the high costs, I decided against it. Moreover, it was not clear whether, after having put the time and effort into a science pursuit, whether career opportunities would compensate. Career counseling on a science career then was sorely lacking..." His point seems to be supported by the fact that although 70% of Cohort 2 students were scholarship holders, there were more of them in medicine/biology/life sciences than in engineering. The "diversification" of the science scholarships is probably in line with the government's mission to develop Singapore into a Research and Development hub for the biomedical sector. Almost 60% of Cohort 1 students had indicated that they had joined SRP to bolster their chances of getting a scholarship. If in fact the number of science scholarships does not decrease, it is likely that science scholarship awards can be used as a means to ensure continued participation in science.

That the SRP only catered to those who were gifted in science is reflected in the fact that none of those who opted out of science, had done so because they had not done well in science. A few of them had in fact done well enough in their 'A' level exams (majoring in math/science courses) to win scholarships to pursue non-science courses at university. A Cohort 3 male had written that he had opted for a management post to "develop other life skills". A Cohort 2 female who is doing very well in a non-science course in an Ivy League university remarked: "Interest in science is one thing, and pursuing a life-long science career is quite another thing to me. I love science, but not to the extent of devoting my life to its advancement". While none of those who opted out of science indicated that they were likely to return to science in the future, a few of them did think their science training would be relevant as new developments take place in tandem with advances in science and technology. As the legal officer put it, "While I am not likely to return to science directly, but possibly in a related way as I am interested in biomedical and bioethical developments which may touch on the law and regulatory environment." Only one person in science said he would be leaving the field because "it is very difficult to progress financially and in stature in a purely science role." A Cohort 2 female scholarship holder said she would venture outside science after she has served the contract because she also "has many interests outside science" and feels she can also contribute in these other areas.

Of the Cohort 3 participants who responded to the section on their career views, a comparison was made between those who were in science careers and those who were not. There were eight items in this section. Table 42 summarizes the extent of agreement of the science and non-science groups on the eight statements.

Table 42

Career views of Cohort 3 by career type

	Science (N=21)		Non-Science (N=9)	
	#	%	#	%
I truly enjoy my work	16	76.2	7	77.7
I do not mind the long working hours	10	47.6	6	66.6
Work is my passion	10	47.6	4	44.4
Work is the most important to me	4	19.1	1	11.1
I do not have difficulties balancing the demands of work and family	13	61.9	5	55.6
I enjoy talking about my work	15	71.4	3	33.3
The work I do has a positive impact on others	18	85.8	6	66.6
I am very satisfied with my present career	14	66.7	6	66.6

While the figures were comparable on most of the items, two stood out. About 20% more of those in non-science careers agree with the statement "I do not mind the long working hours". However, for the item "I enjoy talking about my work", the percentage for those in science careers was more than twice that for those in non-science careers. And it appears that the former also had a stronger sense that the work they did had "a positive impact on others" (85.8 % vs 66.6%).

On the whole, the data suggest that the attrition of SRP participants from science courses and careers is not high, ranging between 10 to 20%. While the extent to which

SRP had any influence on their course and career decisions is not clear, it is apparent that *other* factors were at play. There are myriad reasons to explain why even though participants said they had enjoyed their science classes, and had done well, they still opted for non-science careers. One of them was the lack of scholarships in areas of science that they were interested in. Another reason was their 'other' interests outside science. They could have opted to go into non-science areas 'to develop themselves', or to fulfill other dreams. It is also evident across all three cohorts that their decisions were also made on pragmatic grounds – is there a 'future' for the field they plan to go into? Will the 'hype on biomedical R&D' evaporate like the dotcom bubble? These young people are watching the developments closely. As one Cohort 2 female who has been awarded a scholarship to pursue a degree in medicine and a doctorate put it: "I am watching to see how the biomedical field develops – is it going to be another bubble economy or is the government serious about sustaining a budget for R& D – I would then decide on my final career – whether to be a doctor or a research scientist." Another student wrote: "The Biopolis and current drive of the Singapore government to increase the profile of the life sciences has encouraged me to pursue a research career, as career opportunities have increased." Those who are already in the workforce are also watching developments closely. "Stem cell research and their possible applications in regenerative medicine would possibly have a significant impact on the way curative medicine would be practiced in the future and in turn could have some influence on my career decisions in future", wrote a medical officer. Another who is a doctor by training, and doing research wrote: "Much of biological scientific research is driven by funding, and the availability of collaboration. Backing for translational research is weak in Singapore, despite the resources being poured into basic research. How sustainable this current bout of funding for biomedical science is going to be will certainly guide my career decisions." These new developments have also created a dilemma for practicing doctors. A female was interested to know how other doctors were dealing with this issue of "career prospects and opportunities in various fields of scientific research". She wrote: "I do participate in research work, but my bread and butter is still diagnostics service to the hospital; there is not enough time to delve deeply into research without compromising my specialist work. It would be interesting to find out how practicing doctors feel about the 'divide' between research and service work, as both demand a fair amount of time, and both lead to different types of remuneration, and how much satisfaction they get out of each component and if they feel that their real life situation left anything to be desired in terms of work distribution in their places of employment." Clearly, employment conditions are equally if not more important in curbing attrition from careers in science and science research.

Summary of Question #4 findings

Contrary to expectations, more females than males plan to remain in science. However, a lower percentage of them plan to work fulltime once they become parents. Many factors contribute to the complex decision-making process – whether to continue with science courses at university, to go into science careers, and if so, whether or not to go into research. Although intrapersonal factors are at play, it is also evident that policies about scholarships and employment conditions can influence and shape these students' decisions.

Question #5 Results

The role of intrapersonal factors in students' perception of doing science was the focus of the fifth research question. It ought to be made clear that there were no direct questions on this in the questionnaire. The findings are based on what participants had written in different sections of the survey. This was one way to ascertain if participants were consistent in their answers.

As discussed under Research Question #2, when students were asked to state three essential characteristics for one to be successful in science, across the cohorts, the most frequently cited traits were intrapersonal traits, those "existing or occurring within the individual self or mind" (*American Heritage Dictionary of the English Language: Fourth Edition* , 2000). The most frequently cited factors were curiosity, diligence, intelligence, passion, perseverance, persistence and determination. External factors such as "knowledge", "ability to communicate", "organizational skills", "ability to get funding", and "interpersonal skills" were mentioned by only a handful of participants. From this, it can be inferred that the majority of SRP participants perceived that intrapersonal factors were more crucial than external factors for doing science successfully.

As evident in Research Question #1, when SRP students were asked to report on their own traits, they also tended to check more frequently the intrapersonal traits such as curiosity (88%) about and always questioning (66%) how things work, work hard at something they like (74%), enjoy problem-solving (75%), persistence (59%). External factors like activities they enjoyed and or fascinated them registered lower frequencies. Chi square analyses showed that differences between male and female students on intrapersonal traits were not statistically significant.

In another section where students were asked about their beliefs and values, there was moderate to high degree of agreement with the statements pertaining to the importance of "traits within the mind or individual". Across the cohorts, SRP participants believed that it takes hard work to develop one's gifts, with 95% of them choosing "agree/strongly agree" with the statement (M=3.43). Eighty-two percent of them said that when they made plans, they made sure the plans worked out (M=2.99), and 80% of them said they were internally driven and liked to set goals for themselves (M=3.06). Three-fourths claimed they would persist at something even after others had given up (M=2.97), while 87% of them said most of the time, when they did something they did it because they enjoyed it (M=3.33). These factors are consistent with the intrapersonal traits that participants said they possessed.

Analysis by cohort showed that there were statistically significant differences between the cohorts on several of these intrapersonal items. One-way ANOVAs revealed that Cohorts 1 and 3 differed significantly on the following items: "When I make plans, I make sure they work out" ($F=3.935, p \leq .022$); "Most of the time when I do something, I do it because I enjoy it" ($F=4.139$, $p \leq .018$) and "I would like to be remembered for my contributions to society" ($F=3.908$, $p \leq .022$), with Cohort 1 registering higher means on all three items. The sole item which showed a statistical difference between Cohorts 1 and 2 was "I am a team player and like to work collaboratively with others" ($F=3.360$, $p \leq .037$), with the mean of Cohort 2 at 2.87, compared to 3.14 for Cohort 1. Table 43 reflects these findings.

Table 43

Students' values by cohort

	Cohort 1				Cohort 2				Cohort 3			
	#	%	M	SD	#	%	M	SD	#	%	M	SD
I believe it takes a lot of hard work to develop one's gifts	70	95.9	3.49	.580	49	94.2	3.38	.599	29	96.7	3.37	.556
I believe hard work is more impt for success than talent	62	84.9	3.15	.660	39	75.0	3.04	.791	23	76.6	2.97	.765
When I make plans, I make sure they work out	62	84.9	3.11	.636	45	86.3	2.94	.461	20	66.7	2.77	.626*
I attribute what I have achieved in school so far to my abilities	53	65.1	2.74	.624	37	71.2	2.81	.715	16	53.3	2.53	.629
For one to be successful, good luck is more impt than hard work	20	27.4	2.22	.672	9	17.3	1.98	.610	8	26.6	2.23	.626
I like to set goals for myself I am internally driven	59	71.8	3.04	.735	45	86.6	3.17	.648	22	73.4	2.90	.662
When I do something I do it because I enjoy it	70	95.9	3.49	.580	45	82.5	3.21	.776	24	80	3.13	.730*
I tend to work hard and persist at something even after others have given up	58	79.5	3.04	.676	41	78.9	3.00	.714	19	63.3	2.77	.679
I am nonconformist	58	79.5	2.99	.634	33	63.5	2.77	.783	17	56.6	2.77	.858
I am a team player and like to work collaboratively with others	64	87.7	3.14	.652	38	73.1	2.83	.706	25	83.4	3.00	.587*
I would like to be remembered for my contributions to society	62	84.9	3.19	.680	40	76.9	3.00	.792	17	56.6	2.73	.907*
I tend to be solitary	31	42.4	2.42	.725	26	50.0	2.54	.939	16	53.3	2.40	.724

* $p < .05$

Yet a third source in the survey that corroborated the conjecture that SRP participants perceived the importance of intrapersonal factors in doing science is in the section where they were asked about their perceptions of the SRP. On a scale of 1 (strongly disagree) to 4 (strongly agree), the mean rating on the item " The process of doing research is more important than the end product" was 3.4, a reflection that students felt doing science was as much about developing the individual. A Cohort 2 student made the observation: "For those with a deep interest in science, their SRP experience could make or break that interest – it depends on the person's personal attribute, such as patience, especially when results do not show". A Cohort 1 student wrote "I think talent development is important but the individual must have the self-discipline and the internally driven motivation to excel." Another male from the same Cohort wrote: "I think the maturity level of the individual is another important aspect to consider. I seem to observe that even among the top batch of students (e.g. the gifted) there are two distinct groups: those who do what they want and those who do what they have to. The former invariably ends up as the stronger group of science students, for these people are mature enough to ignore the stress of outsiders". Another Cohort 2 male wrote this when commenting on this study: "I believe the effects of the process are more subtle and dependent on the individual, beyond the ability of a survey to study thoroughly…" A Cohort 3 research scientist summed it up thus: "Talent is common, but talent and the ability to work 36 hours at a stretch, sacrificing family and personal wants is rather more unusual". All else being equal (talent, opportunities), it is ultimately the individual who decides how far he goes and how well he does.

A fourth source indicative of the importance students placed on the intrapersonal role was the reasons they gave for participating in the SRP in the first place

– it was not so much due to 'external' influences like the encouragement of a teacher, the lead of a peer, the pressure of a parent; or even the prospect of enhancing the chance of winning a scholarship to university. It was more to observe how research scientists work, to get a glimpse of life as a researcher, and most important of all, to see if they had what it takes to be a successful scientist. (See Table 23). Indeed, even for those who reached the conclusion that science was not their cup of tea or that they were not cut out for science – this very realization was what they claimed to be the most valuable aspect of their SRP experience.

There were of course participants who felt that the SRP had "turned them off science" either because these participants did not get to work on a project they were interested in, or were mentored by a scientist who, in their view, was not an effective mentor. However, even those who had been "turned off science" went on to major in science at university, and for Cohort 3, some even went on to careers in science. They had persisted in science and/or science research *in spite* of their unpleasant encounters with teachers and/or mentors, or did not find lessons particularly stimulating or enrichment opportunities sufficiently accessible and fulfilling. There were *other* intrapersonal factors at play. Perhaps too, this could partially account for the fact that the majority of respondents said the ***self*** was most important in the talent development process. The external variables appeared not to be strong enough to discourage them from pursuing their childhood goals and dreams.

Summary of Question #5 findings

Consistently, across different sections of the questionnaire, students of both sexes in all three cohorts perceived that intrapersonal factors played an important role in doing science successfully. Whether it was to report on their own traits, or to list the essential qualities of successful scientists, the list was dominated by intrapersonal characteristics. To be sure, SRP participants also acknowledged the role of environmental and external factors – as evident in the credit they accorded to their school teachers, stimulating lessons and enrichment programs, supportive mentors and nurturing parents. On balance, however, it would be fair to say they placed more emphasis on the intrapersonal factors: those who have the internal motivation to capitalize on the environment or overcome external obstacles, and particularly in science, to accept repeated failure, and stay the course are those who are likely to succeed. Indeed, their main reason for participating in the SRP was to find out if they had what it takes to be a successful scientist/researcher.

Question #6 Results

The sixth research question investigated the role parents played in students' academic development, and if this role differed for male and female students. In the last section of the questionnaire, students were given twenty statements pertaining to the role of the home in their talent development. Students were asked about the extent to which they perceived their parents' influence on their education and development. They were asked to rate the statements on a 4-point scale (1=Always, 2=Usually, 3=Seldom and 4=Never). The descriptive statistics are found in Table 44.

Table 44

Descriptive statistics on parental influence - all cohorts

	M	SD
My parents expected me to be among the top three scorers in class.	3.14	.974
My parent(s) would show disappointment when I did not perform up to expectations.	2.77	1.023
My parent(s) would check to make sure I did my homework.	3.18	.908
My parent(s) always compared my performance to that of my siblings and/or my parents' friends' children.	3.11	.912
My parent(s) set very high expectations for me.	2.77	1.074
My parent(s) would praise me for doing well in school.	2.15	.920
I would be afraid to tell my parent(s) if I did not get a good grade.	3.01	.984
My parent(s) discussed interesting science topics at home.	3.23	.778
My parent(s) would set homework for me to do.	3.60	.699
My parent(s) was/were strict with me.	2.68	.924
My parent(s) exerted pressure on me to do well.	2.98	.901
My parents encouraged me to pursue my interests.	1.99	.814
My parent(s) felt it was their responsibility to help me with schoolwork.	3.17	.862
My parent(s) set the number of hours I should study to prepare for tests and exams.	3.77	.520
My parent(s) would buy books for the home to encourage me to read.	2.96	1.044
My parent(s) would take me to the library or museum.	2.94	.920
My parent(s) would explain to me where I had gone wrong when they went through a test or homework with me.	3.42	.764
My parent(s) hired a tutor for me when they felt I needed one.	3.00	1.051
My parent(s) would enroll me for enrichment programs during the vacation.	3.50	.707
My parent(s) expected me to go to university.	1.42	.755

As can be seen, most of the items were rated between "seldom (3) and never (4)". The one item that had the "strongest" rating was "My parents expected me to go to university" with a mean of 1.42 suggesting that parents (>90%) "usually/always" expected their child to have a university education. Apart from this, a few other observations can be made about parents' role, as perceived by their children. Firstly, 42% of students reported that their parents had high expectations of them, and would show disappointment if they did not perform up to expectations, (M=2.77 for both items). However, only 28% of students said their parents expected them to be among the top three scorers in class (M=3.14), or compared their performance to that of other children (M=3.11). It appears that SRP parents expected their children to perform and achieve at their potential, and not necessarily to do better than other students. A second observation is that SRP parents were perceived by their children to be nurturing. The lowest means were for the two items "my parents encouraged me to pursue my interests" (M=1.99) and "my parents would praise me for doing well in school" (M=2.15), with 77% of students awarding ratings of "always/usually" to the first item, and 66% to the second item. A third observation is that SRP parents were not perceived to be very 'active' in their parenting. They did not set homework for their children nor help them with it, only occasionally monitoring them. Although they did set high expectations for the children, they did not appear to be authoritarian or interfering, but were encouraging, supportive, and provided more moral than material support.

A principal component analysis was performed, and it yielded four factors for the role of parents. The four factors can be categorized as follows:

Expectations and pressure: Items 1,2,4,5,7, 10, 11, 20

Active supervision and parenting: Items 3,9, 12, 13, 17, 18

Nurturance: Items 8, 15, 16, 17

Encouragement: Items 6, 12

These results are presented in Table 45.

Table 45

Parental influence - factor loadings

Item		Factor	
1	My parents expected me to be among the top three scorers in class.	1	.712
2	My parent(s) would show disappointment when I did not perform up to expectations.		.793
4	My parent(s) always compared my performance to that of my siblings and/or my parents' friends' children.		.693
5	My parent(s) set very high expectations for me.		.787
7	I would be afraid to tell my parent(s) if I did not get a good grade.		.628
10	My parent(s) was/were strict with me.		.480
11	My parent(s) exerted pressure on me to do well.		.735
20	My parent(s) expected me to go to university.		.457
3	My parent(s) would check to make sure I did my homework.	2	.677
9	My parent(s) would set homework for me to do.		.733
13	My parent(s) felt it was their responsibility to help me with schoolwork.		.693
14	My parent(s) set the number of hours I should study to prepare for tests and exams.		.604
18	My parent(s) hired a tutor for me when they felt I needed one.		.663
19	My parent(s) would enroll me for enrichment programs during the vacation.		.506
8	My parent(s) discussed interesting science topics at home.	3	.790
15	My parent(s) would buy books for the home to encourage me to read.		.751
16	My parents would take me to the library or museum		.700
17	My parent(s) would explain to me where I had gone wrong when they went through a test or homework with me.		.624
6	My parent(s) would praise me for doing well in school.	4	.576
12	My parents encouraged me to pursue my interests.		.794

Reliability

Factor	Cronbach's alpha	Mean	SD
1	.849	21.89	5.3
2	.797	20.21	3.4
3	.773	12.55	2.7
4	515	4.14	1.4

One-way ANOVA was performed to see if there were statistically significant differences in female and male students' perceptions (See Appendix E9 for the ANOVA results). Only one of the differences was statistically significant: 41% of girls (M=2.89) compared to 23% of boys (M=3.23) agreed with the statement "my parents expected me to be among the top three scorers in class" ($F=4.099$, $df=1$, $p\leq.045$). On the whole, compared to boys, girls tended to perceive parental influence more intensely – they reported feeling higher expectations and pressure as well as experiencing more disappointment and praise (See Table 45).

Since the literature suggests that in many instances, participants in gifted or enrichment or mentorship programs tended to come from high SES homes where parents had higher educational qualifications (Bloom, 1987; Feldman, 1991; Imbrosciano & Berlach, 2003), an independent samples t-test was performed to see if perceived parental role was different for students whose parents had different educational qualifications (See Appendices E11 and E12). For this purpose, the six categories of educational qualifications (lower than junior college, junior college, vocational, polytechnic, university, post-university) were collapsed into two categories: those with vocational education and below; and those with polytechnic education and higher. The group statistics by father's education are presented in Table 46. Since the literature also attributes a 'bigger' role to stay-at-home mothers, an independent sample t-test was performed to see if the roles of mothers might be different, based on their educational levels. Using the same categories described earlier for fathers' educational levels, Table 47 presents the means and standard deviations for the two groups of mothers.

Table 46

Parental influence by father's educational level

	Vocational and lower		Polytechnic and higher	
	M	SD	M	SD
My parents expected me to be among the top three scorers in class.	3.44	.861	2.92	1.003**
My parent(s) would show disappointment when I did not perform up to expectations.	2.95	.999	2.66	1.022
My parent(s) would check to make sure I did my homework.	3.29	.837	3.07	.951
My parent(s) always compared my performance to that of my siblings and/or my parents' friends' children.	3.21	.832	3.03	.976
My parent(s) set very high expectations for me.	3.10	.936	2.53	1.119**
My parent(s) would praise me for doing well in school.	2.42	.933	1.99	.872**
I would be afraid to tell my parent(s) if I did not get a good grade.	3.19	.786	2.90	1.077*
My parent(s) discussed interesting science topics at home.	3.47	.671	3.06	.803**
My parent(s) would set homework for me to do.	3.68	.647	3.53	.740
My parent(s) was/were strict with me.	2.69	1.018	2.67	.850
My parent(s) exerted pressure on me to do well.	3.11	.770	2.87	.979
My parents encouraged me to pursue my interests.	1.98	.779	2.02	.839
My parent(s) felt it was their responsibility to help me with schoolwork.	3.35	.812	3.02	.879*
My parent(s) set the number of hours I should study to prepare for tests and exams.	3.82	.426	3.72	.584
My parent(s) would buy books for the home to encourage me to read.	3.31	.951	2.73	1.042**
My parent(s) would take me to the library or museum.	3.13	.877	2.84	.903*
My parent(s) would explain to me where I had gone wrong when they went through a test or homework with me.	3.62	.610	3.26	.833**
My parent(s) hired a tutor for me when they felt I needed one.	3.16	.995	2.88	1.064
My parent(s) would enroll me for enrichment programs during the vacation.	3.62	.582	3.43	.737
My parent(s) expected me to go to university.	1.63	.891	1.26	.554**

* p <.05
** p<.01

Table 47

Parental influence by mother's educational level

	Vocational and lower		Polytechnic and higher	
	M	SD	M	SD
My parents expected me to be among the top three scorers in class.	3.29	.978	2.88	.930**
My parent(s) would show disappointment when I did not perform up to expectations.	2.92	1.051	2.56	.933*
My parent(s) would check to make sure I did my homework.	3.21	.932	3.08	.877
My parent(s) always compared my performance to that of my siblings and/or my parents' friends' children.	3.17	.885	3.00	.973
My parent(s) set very high expectations for me.	2.97	1.043	2.44	1.071**
My parent(s) would praise me for doing well in school.	2.34	.941	1.90	.824**
I would be afraid to tell my parent(s) if I did not get a good grade.	3.12	.947	2.86	1.008
My parent(s) discussed interesting science topics at home.	3.41	.632	2.93	.888**
My parent(s) would set homework for me to do.	3.63	.675	3.53	.751
My parent(s) was/were strict with me.	2.64	.944	2.75	.883
My parent(s) exerted pressure on me to do well.	3.04	.913	2.85	.887
My parents encouraged me to pursue my interests.	2.01	.819	2.00	.809
My parent(s) felt it was their responsibility to help me with schoolwork.	3.25	.847	3.02	.881
My parent(s) set the number of hours I should study to prepare for tests and exams.	3.80	.474	3.69	.595
My parent(s) would buy books for the home to encourage me to read.	3.13	1.008	2.71	1.051*
My parent(s) would take me to the library or museum.	3.01	.932	2.88	.853
My parent(s) would explain to me where I had gone wrong when they went through a test or homework with me.	3.54	.688	3.20	.846**
My parent(s) hired a tutor for me when they felt I needed one.	3.12	1.015	2.80	1.063
My parent(s) would enroll me for enrichment programs during the vacation.	3.60	.630	3.36	.737*
My parent(s) expected me to go to university.	1.53	.805	1.22	.559**

* $p < .05$
** $p < .01$

Comparing the roles of parents, as perceived by students, it appears that both fathers and mothers with higher educational qualifications had higher expectations (M=2.53 and M=3.1 for higher educated and lower educated parents respectively) for their children, and also showered more praise (M=1.99 and M=2.42 for parents with higher and lower qualifications respectively) on them if they did well in school. These parents seemed to play a more prominent role than their less educated counterparts. Children of more highly educated parents reported that parents were relatively more 'involved' in their development, and in the areas like 'discussing science topics', 'buying books for the home', 'explaining homework to the child', and 'enrolling them for enrichment programs', the difference was statistically significant at the $p < .05$ level.

In another section of the questionnaire, students were given 15 statements related to the role of the school and the home in influencing the development of their interest and talent in science. Only the items pertaining to the home are discussed here. When asked to rank on a 4-point scale the extent to which they agree/disagree that the following had influenced their early interest in science, the ratings related to parental role appeared 'weak'; the strongest rating was for the item "freedom to explore own interests" suggesting a hands-off/laissez faire approach of parents, which students perceived was most impactful in their development.

The means and standard deviations for the three cohorts and by gender are presented in Table 48. While all the items had to do with parents/home, the one that specifically stated 'parental influence' had the lowest means (lowest degree of agreement with the statement) for all three cohorts. "Parents work in science field" (M=1.9) was not included in the analysis as it was a 'fact' and the degree of agreement was not subjected to students' perception. When the analysis was done by gender, the pattern was similar. "Parental influence" had about the weakest rating for girls and boys. While the differences among the cohorts were not statistically significant, the differences for gender were significant for two of the items: fewer girls than boys perceived that they had "freedom to explore own interests" ($F=3.948$ $p \leq .049$) and that "presence of non fiction resources at home" ($F=3.948$ $p \leq .049$) played an important role. Given the relatively small size of families, it is surprising that leisure time with family was perceived by less than 40% of students ($M=2.2$) to have contributed to the development of their interest and talent in science.

Table 48

Parental influence by cohort

	Cohort 1				Cohort 2				Cohort 3				Male		Female	
	#	%	M	SD	#	%	M	SD	#	%	M	SD	M	SD	M	SD
parents work in science field	17	23.2	2.03	.781	9	17.3	1.81	.864	4	13.4	1.80	.847	1.87	.854	2.00	.747
parental influence	26	35.6	2.27	.838	18	34.6	2.15	.958	13	43.3	2.30	.952	2.18	.916	2.39	.841
freedom to explore my own interests	67	91.8	3.42	.686	49	84.2	3.44	.608	26	86.7	3.13	.730	3.44	.683	3.20	.632*
presence of non fiction resources at home	53	73.6	2.96	.813	33	63.5	2.81	.864	20	66.7	2.87	.900	2.97	.858	2.67	.778*
leisure time with family	29	39.7	2.37	.791	13	25.0	2.15	.802	10	33.4	2.23	.817	2.28	.833	2.25	.719

* $p < .05$

There were no open-ended questions in the questionnaire for respondents to elaborate on the role their parents played. However, the figures on the "most important person" in their talent development do give us some indication. Comparing the percentages across the cohorts (see Table 38), it appears that the role of parents was diminished, with both male and females who 'nominated' parents as the "most important person" ranging from 17.8 to 16.2%.

Qualitative results

Other sections of the questionnaire were tapped to get at students' perceptions of the role of parents. The following observations were culled from two sources: the first was the question asking respondents about their views on acceleration, and the second was an open question asking if the researcher should have asked something which had been left out. As such, some of these references to the role of parents could only be inferred; but they nevertheless contribute to our understanding of the respondents' perception of the role of parents in the talent development of children.

A male student from Cohort 1 wrote in the open section: "Parents should give the children opportunities to explore the world on their own, even if that means risk is involved. My parents encouraged me to ask questions and find out the answers on my own. They are also very generous in buying books that I am interested in". The role of parents was critical especially when the students were young, and exploring things to satisfy their curiosity, as evidenced in the accounts of the following students.

A Cohort 1 student fondly described his childhood, and alluded to how his parents helped jumpstart his interest: "As a child, I was always very interested in learning, especially numbers. I liked experimenting, such as with the calculator even at a very young age and trying out the different functions just to see what would happen to the numbers. Also, my parents helped by teaching me the fundamentals of calculation just so I could get started." A Cohort 2 male respondent commented on the questionnaire thus: "It appears that the impact of the family has been somewhat neglected. My first experiments and projects were instigated by my father, and I have been consistently invited to join in his projects ever since I was old enough to hold a flashlight. This act of apprenticeship was the foundation stone upon which my subsequent interest in science was developed and one reason why I'm studying to be an engineer..." Another Cohort 3 male who is a medical officer wrote: "I actually think one of the key influences for me were my parents. They have always encouraged my curiosity. I remember with great fondness the chemistry set and the microscope that they bought for me [when I was] in primary school. Bringing me to the library and exposing me to fiction also played a part. I enjoy science fiction and played with what-ifs. Science fiction played a strong role in my interest in the marvels of science".

One student commented that the questionnaire should have probed the "influence of others...more intensively. For students with parents who are lowly educated, motivation comes not only from teachers, but also from friends", suggesting that children whose parents were not well educated were perhaps unlikely to have sufficient simulation from the home. A male student credited the influence of other media like TV, radio for nurturing his interest. "I was obsessed with *Discovery* since young. It's a really good Channel, maybe I was influenced by that". Though this was not a direct reference to the role of his parents, the 'resources at home' had probably been provided by them.

The theme of 'pressure from parents' was another one that kept recurring, albeit in different forms. Those who felt no pressure felt they had the freedom to develop where interests and inclinations led them. Two quotes illustrate this well:

"I think parents and the school both play very important roles. The culture in school is important, so is the environment at home. I think the most effective parents are those that do not pressurize their child, only then can the child perform to his best" (Cohort 1 male). Another Cohort 2 student said what was most crucial to him was the fact that "I had the freedom to pursue my interests, and parents and teachers did not put pressure on me to achieve results. Focus[ing] on learning and understanding rather than the end product was key."

But there were several who felt that 'pushy' parents might coerce children to do things that might be to the child's detriment. The 'caution' respondents sound (about acceleration) can be seen as an indirect reference to the potential harm over-anxious and protective parents can do, when they 'advocate' for the children. A Cohort 2 female wrote: "I agree that [acceleration] would benefit the accelerated children but I believe that especially in the context of the competitive Singapore education environment this would exert too much pressure on the non-accelerated students…*[P]arents will feel obligated to stimulate their children to increase the probability of them being accelerated.*" (emphasis added). A Cohort 3 male worried about children being *forced by their parents* to accelerate. Yet another Cohort 3 male was more direct about pushy parents: "It is fine, provided [the children] are not pushed into doing it. To find out if they are pushed into it is difficult in practice. For example, asking them in front of their parents does not work."

The Cohort 3 students, while acknowledging that parents should be involved in decisions about accelerating a student, were only too aware that children might be 'coerced' by parents (and teachers). One student suggested letting the student set their own pace, "but be sure it is truly their own [decision], not their parents or teachers!" Other however felt that parents know their children best and should be involved in the decision-making concerning the child's development. A Cohort 3 male suggested that parents needed advice on managing an accelerated child, while another felt that parents should have a key role in the decision-making. He wrote: "Ultimately it [accelerating a child] should be a carefully considered decision *on the part of the parent* taking into account the mental and social development of their children. This should not be the responsibility for the educational authorities." (emphasis added)

For a Cohort 3 male doctor, "the most important influence towards a career in medicine/science is the close interaction with parents, peer groups and mentors who have shared the same interest in science whilst I was growing up." Parents who spend time with their children could be equally 'influential' in shaping children's interests and decisions. That only about 17% of students felt their parent was "the most important person" in their talent development can be seen as a fair indicator of the comparative degree of non-involvement of SRP parents, as perceived by their children.

Summary of Question #6 findings

Generally speaking, SRP participants tended to perceive their parents' role as not as important as that of other environmental catalysts. The ratings for the items pertaining to parents' influence tended to be on the weaker end of the Likert scale. Across the cohorts, the trend seemed to reflect comparatively smaller role of parents, with more students in the younger cohorts feeling the 'self' was the most important person in their talent development journey.

There is, however, no doubt that parents had a role to play, as evident in the students' comments in the open-ended section. The role was mostly positive, although a few respondents have highlighted that the role could be a negative one, especially when over-anxious parents become too pushy and coercive. Students perceived their parents' parenting style as not very 'active'; while parents set high expectations, they did not actively supervise their children. Instead, they tended to be more nurturing, providing moral support, and encouragement. There appeared to be a significant difference in the roles of parents, based on their educational levels. Not unexpectedly, the higher the parents' educational level, the higher the expectations and pressure placed on the child to perform in academic areas, and the more involved they were in their children's lives.

Summary of Findings

SRP participants acknowledged the important role of both environmental catalysts and internal variables in stimulating their early interest in science. Of the external factors, it was evident that SRP participants felt more strongly the influence of the school and teachers than that of their parents and the home. Compared to boys, girls seemed more sensitive to external influences. A higher percentage of girls cited as reasons for participating in the SRP "to follow up on teachers' encouragement", and "to satisfy parents' desire to have them participate". Girls also saw participation in the SRP as a way to boost their chances of winning a scholarship to university. More girls than boys also admitted that their continuing involvement in science was due to their good grades in science. It might also be that girls tended to show less confidence in themselves, and needed more concrete affirmation of their abilities (especially in a male-dominated arena – after all, they are outnumbered by boys in the SRP).

These gender differences were not as apparent when the role of intrapersonal variables was examined. It appears that both girls and boys perceived themselves to have traits that are characteristic of people gifted in science, and most of these traits are 'internal' in nature. These include: a strong sense of curiosity, always questioning how things work, intuition, persistence, and working hard at something they like, traits which SRP students associate with successful scientists, as seen in the findings for Question #2.

Across the cohorts, SRP participants perceived science as hard work, and that to be a successful scientist, it was necessary for one to be determined, persistent and persevere in the face of repeated failures. They also rated curiosity highly, and thought it was important for one to always question how things worked.

When asked to assess the impact of the SRP on their talent development, students felt that that the program was more successful in enhancing their scientific and investigative skills than it was in sustaining or affirming their interest in science research. They were clearly cognizant of the fact that they had acquired knowledge and skills way beyond what was covered in their school curriculum. However, they were more ambivalent about the impact their mentors had on them, and their comments on their mentorship experience varied widely, depending on the nature of their project and the personal chemistry they had with their mentors. One feature of the mentorship that was appreciated by the majority of participants, especially those from Cohorts 2 and 3 was the opportunity to interact with peers with similar scientific interests, especially during the residential program at the university. Cohort 1 students, who missed out on this component because of the SARS outbreak, wished there were more opportunity for interaction with like-minded peers. They also felt more keenly the conflict of SRP and school schedules and commitments, and the time-consuming commute to the university took a toll on their enthusiasm.

The role of teachers and mentors in the talent development of children is well-documented (Bloom, 1985; Csikszentmihalyi & Whalen, 1993; Feldman, 1991; Subotnik & Steiner, 2003). Although there were some differences between boys' and girls' perceptions of the essential traits of effective teachers and mentors, all of them valued most highly the trait "genuine interest in student as individual". They looked to teachers and mentors as role mentors, and expected them to show "passion for the subject". They also felt mentors should have a good understanding of their mentees in order to know when to help them and when to let them work independently, and wanted their mentors to be more accessible. Implicit in their expectation of teachers to be willing to discuss topics beyond the syllabus and to be able to teach effectively was the belief that teachers would be well-versed in their content.

Contrary to expectations, more females than males planned to remain in science, although a lower percentage of them planned to work fulltime once they became parents. Many factors contributed to the complex decision-making process – whether to continue with science courses at university, to go into science careers, and if so, whether or not to go into research. Although intrapersonal factors were at play, it was also evident that policies about scholarships and employment conditions influenced and shaped these students' decisions.

Different sections of the questionnaire probed students' perceptions about factors that they felt were most important for one to do science successfully, and consistently, they seemed to feel that intrapersonal factors played a relatively more important role than external variables. Whether it was to report on their own traits, or to list the essential qualities of successful scientists, the list was dominated by intrapersonal characteristics. As mentioned, SRP participants did not discount the role of environmental and external factors, but they placed more emphasis on the intrapersonal factors.

Generally speaking, SRP participants tended to perceive their parents' role as not as important as that of other environmental catalysts. The ratings for the items pertaining to parental influence tended to be on the end of the Likert scale that reflected minimal involvement. Not only that, across the cohorts, the trend seemed to reflect the lesser role of parents, with more students in the younger cohorts feeling that the 'self' was the most important person in their talent development journey.

The role parents played was more clearly amplified in the students' comments in the open-ended section. The role was perceived as mostly positive, although a few respondents, without direct reference to their own parents, highlighted that the role could be a negative one, especially when parents became too over anxious and started pushing children too hard. SRP students perceived their parents' parenting style as not very 'active'. While parents had high expectations, they did not actively supervise nor help their children with school work. Instead, they provided moral support and tried to encourage their children to develop and pursue their own interest and talent areas. There appears to be a significant difference in the students' perceptions of the roles of parents, based on parents' educational levels. Not unexpectedly, the children from homes with more educated parents felt higher expectations and pressure to perform in academic areas, and girls felt this more than boys.

The next chapter discusses these findings further, draws some conclusions, and suggests implications for further research and future practice.

Chapter 5

Discussion, Conclusions and Implications

Introduction

This was a study on the talent development process of a sample of gifted science students who participated in a research mentorship program, the Science Research Program (SRP). Adapting Gagne's (2003, 2004) *Differentiated Model of Giftedness and Talent (DMGT)* as a conceptual framework, the study examined the intrapersonal and environmental catalysts that contributed to the students' talent development in the sciences. It also sought to evaluate the impact of the SRP on the students, and the extent to which it reinforced students' passion for the sciences, and decision to pursue careers in science and /or research. A survey questionnaire (See Appendix B) was used to collect data from three cohorts of SRP participants who were 30, 21 and 18 years old at the time of the data collection.

The discussion section of this chapter focuses on broad themes that emerged from the findings on the six research questions in Chapter 4, and relates these findings to extant literature. Findings across the six questions are synthesized in the conclusion section. This chapter will conclude with implications for policy, practice and future research.

Discussion

Profile of SRP participants

In the literature, students in special programs tend to come from homes with high socio-economic status, as measured by the family's annual income as well as the educational qualifications of the parents. These students tend to be the first born in the family, and have parents who are very involved in their development (Milgram & Hong, 1998). In math/science programs like those run under the auspices of the Study of Mathematically Precocious Youth (SMPY), boys tend to outnumber the girls (Benbow and Lubinksi, 1993, 1995; Stanley, 1993). Many of the students in such programs that have stringent eligibility criteria tend to be award winners, especially, though not exclusively in their area of talent (Olszewski-Kubilius & Lee, 2004; Wu & Chen, 2001). Many are also known to be involved in other extra curricular activities not related to math or science (Bloom, 1985).

SRP students also tended to come from higher SES homes, as measured by parents' educational qualifications and household income. According to the Trends in Mathematics and Science Survey [TIMSS] 2003 report, (Mullis, I., Martin, M., Gonzalez, J. & Chrostowski, S., 2004), 16% of students in Singapore had a parent with at least a university degree or higher, 4% had parents with post secondary/vocational/technical qualifications but not a degree, 21% had completed secondary education, and 59% had lower secondary or less education. Compared to the general population in Singapore, SRP parents had higher educational qualifications, with 48% of fathers and 35% of mothers with at least a university degree, and 38% of fathers and 58% of mothers with high school or lower qualifications. Of the 151 respondents, only 30 (19%) of them had a parent in the science field. However, in terms of income levels, 25% (N=36) of them hailed from homes with annual household income exceeding $102,000, and of these 31 were in the >$122,000 bracket. By contrast, 33% (N=47) of them came from homes with income <$42, 000. Of the 47, 17 had an annual income of <$22, 000. While the highest number came from the highest income bracket (22%), there were also quite a number of low income students in the SRP, 25% with income <$32,000. Just as there were students from high income homes with well-educated parents, there was also a sizeable number whose parents had low educational qualifications, and low income. It can be seen that the SRP profile matched that which is common in the literature, to a certain extent: it does have a higher percentage of parents with higher educational qualifications compared to the general population in Singapore. But what should also be noted is the sizeable percentage of SRP students from homes of modest backgrounds.

In terms of gender distribution, the ratio of boys to girls was 3:1, similar to that in most math/science programs for gifted students. Among those who reported among their achievements participation in an Academic Olympiad (math, information technology and the three sciences), 81% were boys, again a trend consistent with that in the literature (Feng, 2000, Nokelainen, Tirri, Campbell, &Walberg, 2004; Wu & Chen, 2001). About 50% (N=78) of SRP students had studied in the Gifted Education Program (GEP), and of these GEP students, 30% were girls, reflective of the gender ratio in the GEP. The vast majority of SRP students were from the more established secondary schools in Singapore: 114 of the 155 respondents studied in one of the top five ranking secondary schools in the nation, while 143 of them were in one of the top five ranking junior colleges. This is not unexpected since the threshold criterion for applicants is a perfect score (all distinctions) in math and the sciences at the end of Grade 10 exam. As for birth position in the home, 60% were first-borns. More boys (45%) than girls (17%) were involved in science-related clubs in school, a finding consistent with that of participants in a mid-west talent search program (Olszewski-Kubilius & Yasumoto, 1994). The interpretation of this finding though is not as consistent. While Olszewski-Kubilius and Yasumoto contended that boys' involvement in science-related extra curricular activities "probably increases both their knowledge of science and their confidence in studying it in accelerated courses", Bernstein, Garnier & Root-Bernstein's (1995) research showed that there were significant correlations between scientific success and various hobbies, especially artistic and musical ones, and between success and having a board range of forms of exercise. If this were true, then the fact that SRP girls were less involved in science-related activities would not have disadvantaged them. But on the whole, if student participation in extra curricular activities was any indicator, SRP students appeared to have a wide range of interests and were fairly active in school, and did not seem to fit the image of a 'nerd' who excelled only in his studies. Many of the SRP students had won awards in their *other* extra-curricular activities as well.

The importance of intrapersonal qualities

> Let me tell you the secret that has led me to my goal: my strength lies solely in my tenacity.
>
> - Louis Pasteur

The majority of SRP students seemed to perceive that intrapersonal characteristics were important for doing science, and they listed these traits as the most essential for one to be a successful scientist. Their response to this probe was consistent whether the question was open-ended or they had to make forced-choice options. When given a list of 29 traits which, according to the research literature, were common among talented teens gifted in math and science, and asked to check those traits that applied to them, most of the SRP students checked the intrapersonal traits. Apart from abilities like "good at seeing patterns" and "strong spatial abilities", intrapersonal traits like curiosity, persistence, conscientiousness and intuition had among the highest frequencies. The "external" items like activities they enjoyed had comparatively lower frequencies. Additionally, when asked to indicate the most important person in their talent development process, the highest number of them (N=66) chose 'self', compared to 47 who chose 'teacher', the second highest frequency. This is indicative of the relatively greater importance accorded to intrapersonal traits by SRP participants. Interestingly, these traits were also the ones they listed as the 'three essential traits' of successful scientists, when they were asked to list *any* three. If the three adjectives of persistence, perseverance, determined could be said to denote perseverance (*American Heritage® Dictionary of the English Language*: *Fourth Edition.* (2000)), 77% of them listed that as an essential trait. A distant second trait was curiosity (39%), and a third, passion (29%).

Of what significance is this finding? How does it compare to what is in the theoretical and research literature? According to Gagne (2004), author of the *DMGT*, intrapersonal factors are more important than training and learning and the external environment, but less important than chance and gifts in the talent development process. Gifts are a 'given' in the case of the SRP students since they had been selected for this program on the basis of their superior abilities in the area of math and science. Gagne sees chance as all important because it affects everything that an individual experiences and achieves. Since, he attributes his thinking about chance to Tannenbaum (1983), it is pertinent to examine Tannenbaum's thoughts on the role of chance. In an interview he gave in 2002, he said:

> I later discovered that the element of chance is not entirely or necessarily random. There is the phenomenon of "stirring the pot", of being the kind of person who insinuates himself or herself into situations where something combustible is likely to happen ...I thought that the gifted individuals I had interviewed were not just at the right place at the right time, but they *intended* to be at the right place so that at the right time or when the opportunity arose they would be first in line... Then...there is a third level of chance which connects an unforeseen event in the environment and an unforeseen presence of a uniquely equipped person to benefit from that unforeseen environment...So you have the powerful element of chance operating in such a powerful way, but you need to operate with the element of chance in relation to the person *qualified* to make the most of it...(Kay, 2002, p.189. emphasis added)

Chance is not as random and 'uncontrollable' as frequently thought. A master teacher could have taught an individual so well that the student has the depth of knowledge to recognize anomalies in experiments and discern the significance of a "chance observation". An individual with the prerequisite intrapersonal traits can do something to position himself at the right place for the 'right' time; the individual can make himself 'qualified' to benefit from chance – as Pasteur said: Chance favors the prepared mind. The individual wills himself to do something. As Gruber (1998) remarked of Darwin: He *chose* to join a five-year voyage. Freud *elected* to go to Paris. The Nobel laureates in Zukerman's study (1992) undertook *extraordinary efforts* to reach the right teachers, most of whom were Nobel laureates themselves.

While gifts are important, they alone cannot explain the transformation of gifts into talent, or the failure to convert. Hence the vast amount of literature on gifted underachievers. According to Simonton (1998), not all individuals with gifts can 'circumvent the tremendous commitment of pure and unrelenting labor' to convert raw giftedness to adult talent. It takes seven hours a day, seven days a week and ten years for one to acquire the necessary expertise to make the conversion. Those who lack the 'emotional robustness' are likely to fall out of the race.

It is significant that SRP participants perceived the critical importance of intrapersonal qualities to do science successfully. And for many, they had participated in the SRP to see if they had "what it takes". This being the case, it has implications for screening and selection processes. It should be at this stage that personality and interest inventories be administered to help the selection committee ascertain if an applicant was suitable for the SRP, and by extrapolation for careers in the scientific field.

Role of external factors

> To succeed in science ... you must always turn to people who are brighter than yourself. You have to have people you can go to for intellectual help. Constantly exposing your ideas to informed criticism is very important.
>
> – James Watson

The critical role of intrapersonal factors does not discount the importance of the external ones –the role of significant others and environment. Intrapersonal qualities must operate in conjunction with other factors to facilitate the transformation of gifts into talents. Somewhere, sometime in the individual's talent development journey, there has to be a nurturing teacher, mentor, coach or parent; a special regime of learning, training, and practice specially tailored to the gifted individual at critical stages of his development. In this study, the survey probed SRP participants' views of the importance of significant others like teachers, parents, and mentors as well as the environment like the school, the home and the special program (SRP) in developing their talent in science.

Intelligent, interesting, inspiring teachers

> A teacher affects eternity; he can never tell where his influence stops.
> \- Henry Brooks Adams

SRP students' responses about the role of teachers in different sections of the survey were consistent. Apart from the self, the 'teacher' was the second most frequently nominated 'important person' in their talent development. In fact, 'teacher' was chosen by one third of the respondents. In a forced choice section on the factors contributing to their early interest in science, 94% of respondents agree/strongly agree that encouraging teachers played an important role, the highest percentage among 15 items in that section. "Stimulating lessons in school" had the third highest level of agreement with 87%. Did SRP participants' portrayal of effective and memorable teachers conform to that in the literature on effective teachers of the gifted?

That many SRP students had chosen to write about teachers who taught them that many years ago (ranging from more than 15 years to about 6 years ago) is evidence of the lasting impact of teachers' encouragement, advocacy and belief in their students. They cherished teachers who were caring (Stronge, 2002), and interested in them as individuals, especially at the lower grade levels, and encouraged them to follow and explore their interests. At the higher grades, they appreciated teachers who fostered interest in out-of-class activities, and encouraged those so inclined to dabble in research to get a taste of it, and exposed them to out-of school opportunities, and opened doors to possibilities beyond school. At the high school level, the students respected and were awed by intelligent teachers who had expertise in the content area and pedagogy (McBer, 2000, cited in Stronge, 2002), and were able and motivated to share their love of and passion for the subject (Csikszentmihalyi et al., 1993; Rowan, Chiang & Miller, 1997). These teachers were clear and effective in their teaching, modeled curiosity and the urge to learn more, were passionate about teaching and were concerned that students understood the subject, and saw its beauty and applications. Students admired teachers who welcomed unexpected questions from students, and made it a point to read up further to answer them. The majority of the students appreciated the fact that teachers were not preoccupied with grades, and teaching to the exam. In fact, many in the older cohorts attributed their choice of the fields they were in to inspiring teachers. All these characteristics appear consistent with those of the teachers and coaches in Bloom's (1985) talent development study; the 'preferred' qualities of teachers at different grade levels seem to support Bloom's finding that different types of teachers are more effective at different stages of the talent development process. While the SRP students are not at the high level of achievement of Bloom's subjects, their description of teachers at the lower secondary, secondary and high school levels are no less valid: the nurturing teacher who encouraged young students to romance with their interests; the upper secondary teacher who equipped students with prerequisite knowledge and skills to engage in higher level tasks beyond the syllabus, and the high school teacher who modeled for students what is necessary (deep content knowledge, lifelong learning, commitment and passion, etc.) to pursue the field further. The SRP students' unforgettable teachers also seemed to fit in with Csikszentmihalyi and colleagues' (1993) description of 'flow' teachers. The teachers were supportive, warm and caring role models for their students. They love science, have a deep understanding of their curriculum, and never stop trying to find fun and engaging ways to challenge their students academically.

It is interesting that boys tended to write about a teacher in secondary school, whereas girls tended to write about their high school teacher. For instance, among the Cohort 1 students, of the 48 boys, 30 wrote about a secondary school teacher who had left an indelible impression. Of the 18 girls, however, 11 wrote about such a teacher in high school. Yet another interesting finding was that of the 128 respondents who completed this section and nominated a teacher, 53% of the teachers they mentioned were male teachers, compared to 47% females, although the male-female ratio for secondary and high school teachers in Singapore is 35%-65% (MOE, 2003).

Two reasons can possibly account for this trend. First, there are probably more male teachers teaching math and science, and hence the ratio for the overall ratio for teachers in these subject areas at the secondary/high school level is probably more balanced, as reflected in the students' choice of teachers. Second, boys outnumbered girls in the SRP, and many of these boys hailed from single sex secondary schools, and in such schools, the ratio of male to female teachers is probably higher than that for the general teaching force. However, one cannot discount the possibility that men *might* make more effective math and science teachers, especially at the higher grade levels. Among the nominated teachers, three of them have doctoral qualifications in the discipline, and all three are male teachers. This may have implications for teacher recruitment and deployment.

To bring the discussion on the role of teachers to a close, it is pertinent to reiterate that while SRP students might have the requisite gifts and intrapersonal qualities to do 'good' science, they were mindful of the role their teachers had played in nurturing their interests, and molding their growth. The students were fortunate to have had teachers who knew their abilities, interests and inclinations and guided them in their explorations; teachers who were on the look out for appropriate opportunities for them to foster and extend their science-proneness; indeed teachers who believed in them, and advocated for them when their academic performance in other areas could have denied them the chance to participate in enrichment programs in their domain of aptitude. Many of these students had expressed gratitude to these teachers who had radiated love and enthusiasm and played a critical role in setting them on their talent development journey.

SRP participants' glowing portrayal of their math and science teachers is strikingly different from that of the teachers described by Bloom's (1985) mathematicians and research scientists, as well as creative scientists' negative attitudes towards education quoted by Simonton (2004). This can probably be attributed to the different cultural contexts, which will be discussed in a later section.

Caring, motivating, model mentors

> If a child is to keep alive his inborn sense of wonder without any such gift from the fairies, he needs the companionship of at least one adult who can share it, rediscovering with him the joy, the excitement and mystery of the world we live in.
>
> - Rachel Carson

The SRP is a mentorship program. As such, its impact on participants is determined to a large degree by the mentor, and the quality of the mentoring relationship. SRP students were asked to rate their mentorship experience using a 4-point Likert scale. They were also given a list of traits of effective mentors and asked to rank order three of the traits. A considerable number of respondents also wrote about their mentors in the open-ended section that focused on the most and least valuable aspects of the SRP. What qualities did SRP students regard as essential for mentors to be effective? And were these consistent with literature findings on effective mentors? Did SRP mentors, in the view of their mentees, live up to expectations?

Pleiss and Feldhusen (1995) had cited research about children with exceptional talent and the development of prodigies that had demonstrated the importance of intense relationships with adults, including non-kin mentors in the lives of people who successfully transform their gifts into talents and achieve eminence. Mentors, according to Pleiss and Feldhusen "introduce students to ideas, theories, tools, activities or careers in their own fields of expertise" (p.159). In the case of (experimental) science, the essential training for the budding scientist takes place in the laboratory of the mentor where the student learns the tacit knowledge of science (Overington, 1977). The process of collaboration between mentor and mentee is another important aspect contributing to the early productivity of scientists (Long, 1990). Students in mentorships are also socialized to the mentor's work habits, attitudes, values and life style (Pyryt, 2000), since the mentor is also expected to provide guidance toward the life to follow (Casey & Shore, 2000). Mentors also serve as role models – the gifted learner can see in the mentor "an idealized self and in that sense realize possibilities for future accomplishments" (VanTassel-Baska, 1998, p.493).

While there is considerable writing on the role of the mentor, there is not much in the literature on the characteristics of effective mentors. However, one can infer these from the roles described above. In addition to deep expertise and skill in his field, a mentor must have genuine interest in the mentee and seek to understand his needs, and have the enthusiasm to share expertise with bright, young, eager learners. The mentor should be able to understand the level at which these young learners can function, and trust that they will have the ability and motivation to develop knowledge and skills in the career areas of interest. The mentor should feel comfortable sharing his excitement and joy as well as his disappointment with his mentee, and remove the mysterious image of the scientist so that mentees can enter the field with eyes wide open.

Were these the qualities SRP students wished for in effective mentors? The three most important qualities, in descending order of importance were: "genuine interest in mentee as an individual" (M=1.52), "well-versed in his field" (M=1.91) and "passion for the subject/field" (M=1.94). The three most frequently cited qualities were "knows when to help and when to let mentee work independently" (N=81); "creates opportunities to give mentee more exposure in the field" (N=81) and "genuine interest in mentee as an individual" (N=79). SRP students also wished mentors would trust mentees to be capable of work beyond their age level, allow mentees to work independently, and take risks, while mentors provide the safety net should mentees falter. In the open ended section, many expressed how much they valued the opportunity to "discuss scientific matters with mentors in the lab", a reflection of the yearning for intellectual stimulation. A number reminisced fondly about supportive mentors who encouraged them to dare to chase their dreams. Although 'tacit' knowledge was not mentioned, a couple of students mentioned being socialized to the lab politics. Quite a few wished their mentors could make time for them, and rued the lack of accessibility to busy mentors.

In the subsection where students were asked to respond to six items on their mentor, 89% of students thought their mentor was passionate about his work, and 78% felt their mentors exemplified the qualities of a scientist. Eighty five percent reported they had learnt scientific skills from their mentors. On the other hand, a quarter of participants did not agree that their mentor cared for them as individuals; 30% did not find their mentor an excellent role model, and 43% felt their mentor had not inspired them to consider a career in science research. It can thus be seen that SRP mentors were perceived to be more successful in enhancing students' skills and knowledge than in helping students envision future goals and careers. Judging from student responses in the open ended section, there seemed to be an oblique reference to some mentors' lack of understanding of the mentees and their needs – some mentors were not aware of the caliber of their mentees, and were reluctant to involve the mentee in his research, relegating him to a passive observer. Yet other mentors overestimated their mentees' level of knowledge and expertise, and assigned work beyond their grasp.

The lack of personal chemistry between some mentees and their mentors was also partly because of the lack of match between the mentee's interest and the mentor's area of research. For some of them, it was quite meaningless working for months on a project they had no interest in. For example, a biology/life science enthusiast working in an electrical engineering lab was not found to be an inspiring experience. Many SRP students, however, were philosophical about this, and had not allowed a single experience to make them abandon their chosen path – they had gone on to pursue higher studies and very possibly, will enter careers in science. To be fair, part of the problem could be programmatic. Although the mentorship was a year-long one, students met their mentors only once a week for at most a couple of hours, with the exception of the 3-week residential component. Yet, even during this mandatory stay-in period, a few mentees were left to fend for themselves as that was also the term break for the university, and some mentors had taken off for their vacation. These findings have implications for the structure of the mentorship program as well as the preparatory work that is necessary to ensure a better match between mentor and mentee. These implications will be discussed in a later section.

Nurturing, and trusting parents

> Good parents give their children roots and wings. Roots to know where home is, wings to fly away and exercise what's been taught them.
>
> Jonas Salk

In the talent development literature, evidence abounds that parents are a primary influence in the gifted child's talent development process. Parents are sensitive to their child's proclivities, and will do what is within, and sometimes beyond their means, to encourage their child. Parents provide the necessary resources to develop their child's talent area – finances for special and extra instruction and materials, as well as time on sourcing appropriate programs and monitoring the child (Bloom, 1985; Feldman, 1991, Gross, 2004). Parents espouse the values and ethics of hard work, striving, motivation, and set expectations for the child to achieve at the level of their ability. Yet, parents are neither overly protective nor directive. They provide space for their child to explore his interests and dabble in his talent domain, and experience the pleasures and stress of achieving at a high level so that their child would be able to cope with obstacles. Of course parents are always there to provide support and love when the child gets discouraged or frustrated. Csikszentmihalyi and associates (1993) found in their research on talented teens that children from families where there is a balance between support and high expectations have the highest chance of developing their talents to a high level. Parents know *when* to give their children wings. Had Darwin's father not allowed him to set sail, Darwin might not have found his compass in life (Howe, 1993).

Another strand of literature dwells on the role of Asian parents in their child's development, although most of the studies tended to focus on Asian parents' parenting practice in the American context. Generally, the thinking is that Asian parents place a high premium on education and achievement, and are therefore more likely to be more integrally involved in their child's talent development, especially if it is in an academic domain (Goyette, & Xie, 1999; Le Maistre & Kanevsky, 1997; Wu & Chen, 2001). Asian parents have high expectations of their children, and see education as a means to social mobility. What kind of families did SRP students come from, and how did SRP students perceive the role of their parents in their talent development?

First of all, SRP students tended to come from small families, with a mean of 2.3 children. Yet, the families did not appear to be close. Only 33% of the respondents felt that leisure time with the family contributed to their early interest in science, even though many of them reported being interested in science from a young age. Among the various factors in the section probing the role of parents and the home in the student's talent development in science, the majority of students mentioned "high expectations" and pressure to perform well. SRP parents with higher educational qualifications tended to have higher expectations, a finding consistent with research in the literature (Bloom, 1985; Mullis, et al, 2004). While both boys and girls reported high pressure to perform well academically, girls felt the pressure more intensely. One reason could be girls' need for more affirmation makes them more willing to please authority figures, and to be more conforming, and hence more sensitive to external pressure (Le Maistre & Kanevsky, 1997; Olzewski-Kubilius, 2001).

The theme of attentive and active parental support, direction, and encouragement that emerged in Bloom's study (1985) was absent from this study of the SRP sample. Most of the SRP participants' parents never or seldom "help them with homework" or supervise them. They also did not take their children to the library or museum, nor enroll them for enrichment programs during the vacation. But 77% of students reported that their parents encouraged them to explore their own interest, while 90% said they had the freedom to explore their own interests. Sixty six percent reported that their parents "always/usually" praised them when they did well. This percentage rose to 92% if students who said parents 'sometimes' praised them for doing well were included. In terms of degree of parent involvement or style of parenting, again the SRP parents did not seem to fit the pattern reported in the research.

Unlike parents of science Olympians (Feng, 2000; Nokelainen, Tirri, Campbell & Walberg, 2004; Wu & Chen, 2001), SRP parents were perceived to be less involved in their children's lives, although not necessarily less supportive. Almost equal percentages of students had parents who always/usually (30%) took them to the library or museum, and who 'never' (32%) did that. Thirty percent of students had parents who always/usually bought books and encouraged them to read, compared to 40% of students whose parents 'never' did that. The picture that emerged of the SRP families is one where parents appeared to be not so proactively involved in their children's academic life. SRP parents tended to be more autonomy-granting. Several reasons can be advanced to account for this. First, 40% of the families were dual income families, and parents could be less involved because of career commitments. Second, although 60 (40%) of the participants' mothers were stay-at-home moms, only 20% of them had polytechnic or higher qualifications, suggesting that 80% of the stay-at-home moms perhaps did not have the capacity to actively help with their children's school work or monitor them. Third, it could be that parents relied on schools to provide the necessary enrichment programs, and therefore they saw less need to scout for privately run ones for their children. Students' feedback that enrichment programs in school (87%) and participation in enrichment programs that emphasized science learning (78%) contributed to their early interest in science seemed to support this. The TIMSS 2003 report (Mullis et al, 2004) also attributed Singapore students' good performance to the fact that Singapore had the highest *Index of Availability of School Resources* among participating countries. Finally, culture could also partially account for SRP parents' lower level of involvement in their children's education. In an achievement-oriented culture where educational achievement carries a high premium and where there is economic motivation to excel in math and science, students regard doing well in these subjects as important. There is thus less need for parents to supervise their children, especially if their children are gifted and highly motivated, like the SRP students. This is a message that is relevant to all parents, regardless of SES status. Provide the necessary moral support; give the children space to follow their inclinations, and explore their myriad interests, but do not smother their enthusiasm. One does not have to be well off to nurture talents in the home – especially in an environment where merit is the basis for placement, and where schools and other educational agencies can provide the needed resources and facilities to develop and nurture talents.

Program Impact

Other than the role of significant others like teacher, mentor or parent, there is also considerable evidence that formal training and practice and programs and courses, designed to nurture gifted children's potential have proven to be necessary and effective in converting gifts to talent (Benbow & Lubinski, 1995; Bloom, 1985; Feldman, 1991).

Since two of the cohorts in this study had not graduated from college, it would be premature to judge if they had successfully converted their gifts into talent. But that does not detract from the fact that they had remained in science courses, and intended to stay in the science pipeline. To what extent can this be attributed to the impact of the SRP? Although 79% of respondents gave a rating of 3 or 4 on a scale (where '4' was to a great extent and '1' was not at all), the percentage that agreed that the SRP made them surer that they wanted to pursue a career in science was only 55%. The findings showed that it was the accelerative feature of the SRP that had the greatest impact: SRP had deepened their knowledge beyond what the school curriculum could offer (94%), sharpened students' scientific skills (85%), and further stimulated their interest in science (83%).

Another feature of the SRP which was important to the participants was the opportunity to interact with peers with similar interests. Students' responses analyzed by cohort differed markedly. While 88% of Cohort 2 students agree/strongly agree with it, 43% of Cohort 1 students disagree/strongly disagree with this, and the difference was statistically significant at the $p < .001$. Cohort 3 students' view was somewhere in between, with 70% agreeing or strongly agreeing with it. Another finding that has implications for the program structure has to do with the adequacy of time to complete the project. Again, Cohort 1's response on this was less positive than the other two cohorts. Only 55% of Cohort 1 agree/strongly agree with this, compared with 71% and 68% respectively for Cohorts 2 and 3. Comments in the open-ended section provided some possible reasons for this trend. Cohort 1 students bemoaned the lack of opportunity to experience the residential component which had to be cancelled because of the SARs outbreak in Singapore. This cohort also seemed most affected by the conflict of schedule, and found great difficulty balancing the demands of school work, and completing their SRP project. Another grievance they had was the time-consuming commute to the university. By contrast, Cohorts 2 and 3 students reveled in the opportunity to befriend intellectual peers with similar interests from other schools and other countries, especially during the stay-in phase of the program. Witnessing what other SRP students were doing was an eye-opener to some. A few talked about the late nights in the labs waiting for results, probably a common feature of research in certain fields of science. It appears from their qualitative accounts that the two older cohorts' experience of science research was 'more authentic'. These findings have implications for the programmatic aspects of the SRP which will be discussed in a later section.

Experience with doing science

Brandwein (1992) maintained that science should be learned by *doing* since science is 'a way of knowing', and a 'process'. To him, an environment that encourages inquiry provides the best opportunities for *all* students to learn, because then students with the appropriate interests and abilities will gravitate towards scientific activities with the appropriate level of challenge (Brandwein & Passow, 1989). This is somewhat analogous to the initial stages of talent development that are described by Bloom and his colleagues (Bloom, 1985; Subotnik, Olzewski-Kubilius, & Arnold, 2003) as setting a stage for romance within the area of study or field of inquiry. The involvement in these scientific activities would be beyond the regular school curriculum and involve time outside school hours. Admission to these programs should be based on self-selection and self-identification, where the students 'volunteered' to undertake the additional course/program, and among those in the program, a few will self identify to undertake 'originative' work. Self-identified students engage in the 'suspenseful heuristic mode' of problem solving, an almost real-life simulation of what scientists do. Teacher-mentors observe these students for behaviors that underlie the expression of science talent - questing, and persistence.

There were no questions in the survey pertaining to Brandwein's philosophy. Unsolicited comments from the students, however, offer a glimpse of the 'ecology of achievement' in the students' science education. The nostalgia about their early school days (primary and secondary levels) seemed to reflect their resonance with Brandwein's (1995) idea of self-selection and self-identification. A Cohort 2 female wrote: "Education in science in primary school was crucial in developing my interest in science; as I was in the science club and often did projects for the young scientist awards which piqued my interest in doing simple scientific projects." Membership in science clubs is by self-selection. A Cohort 1 male described his secondary school science club: "…the Science Club has been critical in influencing my development in science, and similarly for several of my friends. It is difficult to put in words but I strongly suggest the researcher to take a look at this club…" His club mate alluded to the freedom to explore any scientific question they were interested in, the support they had from their teacher, and the fun they had in these explorations. Teachers, resources, and school culture made a tremendous difference to a Cohort 2 female who attributed her love for learning and science to her school: "Teachers encouraged students to question, offered students resources to explore their talents such as arranging programs or projects to do outside of class time, instead of just focusing on the 'O' levels. It is also important to have labs available or facilities to explore simulated experiments and link up with science enthusiasts overseas; ...the culture in the school – students have a general spirit of questioning what we learn and taking the trouble to find the answers...all of which were available in my school – it was the school that nurtured my love for learning..." These descriptions of invitations to participate in programs outside class hours were conspicuously absent at the post secondary level. Indeed, a Cohort 2 male critiqued the over emphasis on academic results as a prerequisite to participate in programs like the SRP: "SRP should not be for science elites. It should be a program for those who are willing to work hard and truly want to do research. There should not be an 'O' level cap for SRP entry. Instead a scientific and psychological test could be used instead, in addition to having the applicant submit a proposal. What matters is that a chance is given to those who work hard for it. Not those who 'deserve' it simply because they did well in the 'O' levels". From the voices of these few vocal students, one can sense their agreement with self-selection and self-identification, and it appears that students were afforded this more often *outside* the curriculum.

While there is general agreement that interest in science should be nurtured in children from an early age, there was less agreement on *how* that should be done. One school of thought places more emphasis on science content and skills, and advocates exposure to science content as early as possible (see Fensham, 2000). Critics of this view have pointed to state standards for science and claimed that the 'strong bent' towards facts will force teachers to teach in a superficial manner in order to 'cover material'. This will inevitably lead to rote learning and leave little time for building conceptual understanding (NRC, 2002; NSB, 2003; American Physical Society, 1998). The upshot of this would be children learning rules without understanding, and cease being the "wonderful scientists they are in their earliest years" and being turned off. Early childhood educators believe that children should be given opportunity to discover and reinvent science. Children need the time to discover, to learn how to satisfy their curiosity, to ask good questions like what good scientists do. And to do that, science-prone students should be exposed to non-science areas as well. Research on creative adults has shown that the scientist inventor who has switched disciplines brings ideas that are alien but helpful to the new domain (Simonton, 2004), affirming Csikszentmihalyi's (1999) finding that creative people made major contributions by going beyond the original domains, and connecting different domains with each other. To him it is rare to find real change that comes from burrowing more deeply into a single domain. Shavinina's (2004) study of high functioning Nobel laureates led her to the conclusion that their creative functioning is determined in part by their "intuitive processes, [and] subjective feelings and beliefs..." Teaching science with preordained conclusions and through canned experiments is likely to kill these very qualities that ought to be nurtured in budding scientists.

The few SRP respondents who mentioned the science curriculum seemed to favor a 'broader' curriculum and not one that is focused on science content only. To a Cohort 2 male, "passion could be squelched at an early age by burdening children with technical skills and studies. [It is] more important to cultivate interest and cognitive ability i.e. logical reasoning, causality, and association. Technical knowledge will come sooner or later when kids go to university…" A Cohort 2 female shared her personal experience in primary school: "I fondly recollect the mathematical investigations and stimulating activities that have had such deep-reaching influences on the way I think about science and other subjects. This was because we had the opportunity to pursue *other* subjects which were rather different from the conventional curriculum such as prime numbers, Greek mythology, more advanced literature, all of which were 'landmark events' in my education. A Cohort 3 male also felt that it is more important to cultivate 'questing' from an early age. In his words: "My personal opinion is that a scientist is best developed when a questioning attitude towards authority and established dogma is developed in the formative years. This is best served by topics in philosophy, politics, religion and history, rather than field trips to chicken farms for students. Unfortunately, these topics are often considered as irrelevant and too sensitive. I think that an interest in science/math/electronics during this period is helpful but not essential. Craig Venter, Jim Kent, and Judah Folkman are classic examples of people who did not show initial promise in science but excelled when they entered the field…" The respondents' description of their school experiences and how they have impacted their talent development in the sciences have implications for practice.

Gender issues

> I have a great deal of work, what with the housekeeping, the children, the teaching and the laboratory, and I don't know how I shall manage it all.
>
> Marie Curie

The literature on the conspicuous lack of gifted girls in advanced math and science classes as they progress up the grade levels, and the alarming attrition of women from math, science and engineering courses and careers has already been surveyed in Chapter 2 (Hyde & Kling, 2001; Reis & Park, 2001; Stumpf & Stanley, 1996). There is research evidence from the SMPY study that boys outperform girls in math (Benbow & Lubinksi, 1993; Stanley, 1993). Subotnik, Steiner and Stone's (2001) longitudinal study of Westinghouse (Intel) winners also showed that a higher percentage of women than men opted out of science. To Lubinksi and Benbow (1995), this was because "gifted females value social and aesthetic pursuits more highly than the theoretical sentiment [of] their male counterparts…gifted females would be anticipated to be relatively equally committed to educational and career tracks involving aesthetics, social and theoretical domains. In contrast, the males should be expected to be inordinately represented all along the math/science pipeline" (p.269). Arnold's female valedictorians' career goals also lagged behind those of their male contemporaries, because the young women were concerned about finding a balance between family goals and career aspirations (1992). Kerr and Nicpon (2003) also found that gifted women were more likely to give up full time work for part time work than gifted males because women still bear the primary child rearing responsibilities.

Many of these gender issues are relevant to the findings of the SRP study as well. To begin with, the boys in the SRP outnumber the girls 3 to 1. So, it does seem that the trend of girls' absence in high level math science programs is borne out by the three cohorts in this study. However, there is no basis in this study to speculate if the reasons for this trend are similar to those cited in the literature, and this has to be an area for future research. But what is pertinent here is that the 25% girls who are in the SRP must be quite different from the girls who avoid high level math science courses and programs. It is not surprising, therefore, that many of the issues raised in the brief summary of the literature findings do *not* apply to the SRP girls.

In terms of performance in math and science, the girls outperformed the boys in math, biology and chemistry. Although this was consistent with findings in the 2003 TIMSS report (Mullis et.al, 2004) where at Grades 4 and 8, girls in Singapore did better than the boys, the difference in this study is that the comparison was in performance in high level math/science courses. Even in 'S' paper candidature for math and chemistry, the girls outnumbered the boys. Unlike girls in the literature, SRP girls did not shun 'difficult' courses. One of the reasons for this could be that they were more likely to respond to extrinsic motivators – the encouragement of a teacher, the desire to please a parent, or the attractiveness of a scholarship. Indeed, the girls could have perceived a greater need to 'prove' their worth by participating in a prestigious program like the SRP that is meant for the very best high school science students since the high level math/science competitions are already dominated by the boys. It might not be a coincidence that the majority of the holders of science scholarship awarded by the Agency for Science, Technology and Research are females (Chang, 2004). A higher percentage of SRP girls than boys were enrolled or planned to enroll in science courses in college, and to pursue careers in science. Once they had discovered their affinity and aptitude for science, they planned to pursue their goals, and stay the course notwithstanding the experience they had in the SRP and with mentors. Ninety-three percent of SRP girls, compared to 70% boys, perceived perseverance, determination, and persistence as essential in order to be successful at science. It seemed they were prepared for the obstacles in their path, and had the stoicism and resilience to overcome them, come what may.

There is the perennial problem of conflict between family priorities and career aspirations for the females, however. Eighty percent of the Cohort 3 females (now aged 30) had already decided that they would not work full time when they became mothers. Although only three females from Cohorts 1 & 2 had indicated they would work part time when they have children, the number is likely to be higher when the time comes for them to make the decision. After all, they are no older than 21 and still in school.

Conclusions

The three cohorts of SRP participants were the best among their age peers, having been selected for the SRP on the basis of very stringent criteria. It appears that across the three cohorts, of the various catalysts in Gagne's *DMGT* (2003,2004), the perception was that the role of the self was the most important in their talent development journey. The majority of them felt they had the intrapersonal qualities that were essential to be a successful scientist – deep interest in what they do, curiosity to find answers to questions, willingness to do hard work and work hard, and strong will to persist and persevere when things get tough. Although broad themes could be discerned in their commentary on the role of external catalysts, it was evident that these catalysts were experienced in a very personal, individual way. As one respondent who did not have a 'satisfying' experience with his mentor put it: "Failure, rather then success was the source of my motivation to pursue my interest in science." Another student attributed his passion for biology to a quirk of fate – he had such a 'terrible teacher whom [he] could not depend on, that he had to rely on himself to learn more'. Another student could have responded by "switching off".

As for the impact of the environmental catalysts, it was evident that the school and teachers were perceived to be more influential than parents and the home, as reflected in the quantitative data. The majority of respondents were very specific about the way their teachers inspired and encouraged their interest in math/science, nurtured their talent and motivated them to develop their potential to the full. Above all, they cherished teachers who cared for their overall development and well being, and showed genuine concern in them as individuals. For those who experienced self doubt along the way, they still remembered and were grateful for the teachers who had faith in them and advocated on their behalf. In most instances, students were also very positive about their experiences in school – the stimulating lessons, the enrichment programs and the co-curricular activities. The only complaint was the occasional reference to the need to prepare for national examinations which required rote learning. Yet to the credit of the teachers, the majority of students reported that their teachers were not obsessed with preparation for national exam, but were keener to instill love for, and understanding of the subject.

The SRP students' glowing portrayal of their math and science teachers is strikingly different from the generally unflattering depiction of teachers in the literature (Csikszentmihalyi, 1996, Veltman, 2004). Bloom's (1985) mathematicians and research scientists' descriptions of their math/science teachers were not very positive while the creative scientists quoted by Simonton (2004) certainly had very negative attitudes towards their teachers. What could account for this palpable contrast in the gifted youth's attitudes towards their teachers? Part of the answer could be the difference in cultural contexts. Teachers in Singapore are held in high esteem. A recent survey commissioned by the Ministry of Education found that members of the public ranked teachers as having contributed most to society, above doctors and lawyers (Shanmugaratnam, 2005). It is thus likely that students already have an inherent respect for their teachers, and are more inclined to see their role in a positive light. There is also research evidence that suggests that teachers in Singapore *are good* at what they do. According to the Minster for Education, the positive public perception of the teaching profession has helped to attract more talented people to the teaching service (Shanmugaratnam, 2005). Research on factors that motivate people in Singapore to become teachers consistently show that the five most influential motives are "love working with children"; "love teaching"; "influence young lives for good"; "teaching is intellectually stimulating" , and "teaching is a noble profession" (Goh & Atputhasamy, 2001; Soh, 1989, 1998), motives that seem to epitomize the teachers described by the SRP students.

The data suggested that SRP students perceived their parents as supportive but not directive in nurturing their interest and talents in science. To be sure, there were high expectations – of achieving at their level of potential and the ethic of hard work – but SRP parents did not seem to be 'pushy' nor actively involved in their children's development. The majority of them did not supervise their children in homework, nor monitor the hours spent on it. The most commonly cited active involvement was in buying non-fiction books and resources for the home, and encouraging the children to explore and pursue their own interests and propensities. It seemed like a laissez faire parenting style that was appreciated by the children.

Across the cohorts and for both male and female students, a year's participation in the SRP had undoubtedly deepened their knowledge of science beyond what the school curriculum could offer, sharpened their scientific investigative skills, and further stimulated their interest in science. These aspects of the program were perceived as being impactful. On average, between 55% to 65% of students felt that the SRP affirmed their interest in science research, strengthened their resolve to pursue science at university, and made them surer they wanted to pursue a career in science. It is noted, however, that the percentage seemed to get higher with each cohort. This could be attributed to the fact that the older cohorts unlike their juniors had the retro perspective and were able to compare their SRP experience with that they had in college, or it could be indicative perhaps that the program is getting better at meeting program objectives and the needs of its participants. In any case, those who had decided not to continue with science appreciated the fact that the SRP enabled them to realize that science/research/ academia was not for them. One aspect that was very much valued by students was the residential phase of the program which provided an excellent opportunity for them to interact with peers who were equally impassioned about science.

Overall, the conclusion one can make about the study findings related to the program itself was that SRP participants started with the aptitude and the interest in science, and the SRP had fueled this interest further. In most instances, it was the 'self' that had shaped their future decisions. They appeared to be clear about their future academic and career plans and seemed savvy about employment conditions and prospects and were prepared to pursue their goals regardless of their experiences in school, and at college. While positive encounters with mentors and teachers might have nudged them towards their goals, less satisfying relationships with mentors did not seem to have deterred them. The leakage from the science pipeline does not appear to have had much to do with the SRP.

Implications for research

The findings of this study have important implications for further research. Three cohorts of SRP participants had been surveyed for their views on the factors involved in their talent development in the sciences. They had shared insights about the influence and impact of their teachers, parents, mentors and the role of the school, the home and the SRP on them. What this study has not been able to do is to probe the influence of 'elite peers' (Subotnik & Olszewski-Kubilius, 1997), and *how* the opportunity to live with and socialize with peers and professionals have shaped their development.

Future studies could be undertaken to gather the views of the environmental catalysts – teachers, mentors and parents - on their perceptions of how they have contributed to the nurturance of budding scientists in their midst. Are effective teachers aware of the impact they have on their students? Can they articulate their philosophy about teaching and talent development? Can their 'best practices' be captured and shared with others to raise the quality of teaching? How do effective mentors enthuse their mentees? How do they deal with mentees who they are not compatible with, or whom they think are not cut out for a career in science? What can effective mentors share with other mentors to improve the quality of mentoring? What are effective mentors' views on the selection of SRP participants? How do parents know if their child is blessed with gifts, and what do parents do to nurture them? What kinds of parenting styles are effective for what types of children? Are there 'best practices' in parenting that are universal? Using the data base generated in this study, in-depth case studies of selected students, teachers, mentors and parents could be mounted. These studies can sharpen the 'general' image we have of the talent development process and inform future practice. Longitudinal studies of participants in talent development programs like mentorships would also shed important light on the career trajectories of gifted science talents. Such studies can contribute to the empirical knowledge linking early potential to adult productivity.

Another study that ought to be explored is why there are so few girls in the SRP and other high level math and science programs like it. Based on the findings of this study, the girls seemed to perceive their experience very positively and appeared more likely than the boys to stay in the science pipeline. Already, girls are grossly underrepresented in the Academic Olympiads (Feng, 2000; Nokelainen et al., 2004; Wu & Chen, 2001). If there is truth in the possibility that girls unlike boys do not thrive on competitions, something ought to be done to encourage more girls to participate in non-competitive programs like the SRP. The suggestion is not to lower the bar for girls but to examine the application rates – are enough girls applying? If not, why not? Since none of the SRP girls reported ever being discouraged by anyone from pursuing science, a survey of gifted female science students who are *not* in the SRP would be important to ascertain the factors deterring their participation, and what, if anything could be done to rectify misperceptions if they exist.

Implications for practice

The findings of this cross sectional study have some implications for mentorship and talent development programs for the science-inclined. Although there is a twelve-year interval between the time Cohorts 3 and 1 were in the SRP, and much has changed during the decade, it appears from their feedback that what matters in talent development has not changed much. All three cohorts affirmed the importance of passion and perseverance, and the need to commit to work hard, and make some sacrifices. They acknowledged the inspiring influence of effective teachers and mentors. They recognized the support of their parents and the freedom accorded them to explore and pursue their interests. The participants also seemed to know what they wanted out of the experience, and for a good number of them, it was their mentoring experience, and not their mentor per se that shaped their views and feelings about pursuing science further, and developing their talents in the domain.

There is a message here for all who are involved in developing talents. Parents should be encouraged to help children find their own strengths, and select schools and programs that can best develop these strengths. Schools, teachers, and any agency organizing programs to develop science talents ought to take these findings into consideration when making decisions about selection criteria, structure of the program, nature of the activity, timing and duration of events, and type of resource support to enhance the chances of positive experiential learning. This will be discussed further in the epilogue on a proposed mentorship program model for talent development in the sciences.

Many of the implications for practice arising from this study are also pertinent to the SRP committee as many concern the implementation of the SRP itself. The first has to do with the screening and selection process. The majority of SRP students in this study had perceived intrapersonal qualities as most important in their involvement in science. Yet, none of the criteria for selection of SRP applicants had anything to do with this. Perhaps, the screening process for the SRP should be the appropriate stage to see if applicants have the requisite non-cognitive traits. The current practice of selecting SRP participants predominantly on the basis of their performance in math and science at the end of Grade 10 exams, and the science aptitude tests does not appear sufficiently comprehensive nor appropriate in light of this finding. The only measure of applicants' perseverance is whether or not they managed to complete six weekly sessions of the Research Methods Module, a series of lectures by NUS professors held one afternoon a week during term time. Since all who attend the six sessions will receive a certificate of attendance, 100% attendance cannot really be equated with perseverance. Even teachers' rating of an applicant's suitability is no longer a requirement. Perhaps applicants could be asked to do a brief write up listing say, two personal attributes they have which they think can make them successful in science or suitable for science research. They could be asked to complete a personality/interest inventory, and to ask a science/math teacher who knows them well to independently complete the personality inventory on them. This would bring more congruence between the selection process and the intrapersonal factors

SRP participants perceive as important to succeed in the program, and in the field, a perception that is supported by research (Benbow, Lubinksi & Sanjani, 1999; Brandwein, 1995; Piechowski, 1999; Simonton, 2003). In fact, the SRP committee might consider professional development for SRP teacher-liaison officers and science teachers on talent spotting since they are the people who are most likely to observe the science-prone students in naturalistic settings.

A fuller profile of SRP applicants could possibly enhance the match between mentor and mentee. The unique feature of the SRP is *the mentoring relationship.* If greater care could be taken to produce compatible matches, this would lead to productive, lasting relationships that would augur well for future collaborations between mentors and their protégés. Recognition of effective mentors by way of awards as well as publicity for mentees and mentors who attain exceptional achievement (e.g. a joint publication in a prestigious peer-refereed journal) could also encourage more professionals to view mentoring more positively.

A third implication for practice pertains to the program structure. It appeared that participants had to observe a one-size-fits-all schedule regardless of the nature of the research study. While several participants rued the pointlessness of weekly face-to-face meetings with mentors when there was no result nor development to report, others felt that daily meetings were necessary as the 'thing' they work on does not grow in weekly spurts. The suggestion is for organizers to consider allowing the former to substitute meetings with telementoring, while at the same time making provisions for the latter to be granted leave from school for a term or semester to work fulltime on their projects at the university. Students were quick to point out that this would be 'less problematic' now that students in schools offering the Integrated Program need not prepare for end of Grade 10 exams.

It also appears that organizers have discontinued the residential component of the program since the outbreak of SARs in Singapore in 2003 (Tan, personal communication, February 1, 2005). There is good reason for them to re-consider this decision – many of the Cohort 2 and 3 respondents felt it was 'most valuable' to have the opportunity to live with and meet students and professionals who shared similar passion for science. And fewer of the Cohort 1 students agreed with the statement that the SRP provided them with opportunity to interact with intellectual peers. Of course, some flexibility would be necessary. Students whose labs are closed or whose mentors will not be in campus should be given the choice to opt out of the residential component.

Finally, about 75% of the SRP students are prepared to serve as SRP mentors. It might be timely for the SRP organizers to consider setting up an SRP alumni, keep in touch with SRP graduates and tap this rich resource for mentors. If more of SRP alumni can return to serve as mentors, there is a greater chance of successful mentorship experiences for future SRP participants.

Another implication for practice pertains to the deployment of science teachers. Clearly, gifted science students need teachers who are well versed in their specialties to provide diversity and depth in their courses. Teachers must have adequate expertise to guide gifted students in addressing significant and meaningful problems. Years of teaching experience do not seem to matter much, as long as teachers share their passion with students, care for them as individuals, recognize their talents, and encourage their development instead of focusing all of the energies on preparation for national exams.

Implications for policy

It is evident from this study that some of the policy measures that have been taken to attract more gifted students to science have been successful. Seventy percent of the respondents who are heading for science careers are scholarship holders, and the fields they plan to enter appear diverse, and in areas where Singapore faces a keen shortage of expertise. But to ensure success over the long term, reforms have to be in place at the earliest levels. To ensure a steady pool of eligible scholarship applicants, schools have to be effective bastions where young people's passion for scientific inquiry will be ignited. More opportunities like the SRP should be available for the self-identified science-prone who are committed to work to convert raw aptitude into talent. With the growing presence of foreign conglomerates involved in research and development, some policy could be put in place to encourage these establishments to collaborate with local partners like the university to develop scientific talents in the field. With different levels of initiatives targeted at developing different levels of talent, chances are that leakages from the science pipeline could be preempted.

The dilemma that scientists (e.g. scientist-doctors; scientist-professors, scientist-moms) face about balancing research and providing service is a real one that needs to be addressed. Even as measures are taken to attract more foreign talent to Singapore, steps also should be considered to prevent the outflow of Singaporean talent to places where research opportunities are perceived to be more abundant. While the government has already abolished the quota on the number of female doctors, it needs also to examine employment conditions to ensure that talented and well-qualified female scientists are not lost from the field permanently when they take time off to fulfill child-rearing duties.

Epilogue: A Program Model for Talent Development in the Sciences

In the final analysis, what do the findings and implications of the retro-perspective study across multiple cohorts mean for talent development? A useful way to discuss this would be to synthesize them in the form of the major components of an ideal program model. The description of such a model follows. (See Figure 3 on p.232).

Student selection

Students will be selected on the basis of multiple criteria. In addition to demonstrated aptitude and interest in science, other criteria would be used to yield a fuller profile of applicants. Checklists and recommendations of math and science teachers would be important as they are the people who have observed students in naturalistic settings, and would be in a position to report on their behaviors, especially those that underlie the expression of science talent, like questing and persistence. Students' participation in extra-curricular activities in school, and student-completed inventories and personal statements of reasons for wishing to participate in the mentorship program would also shed light on students' level of interest in science and science research, their perceptions of doing science as well as qualities they possess that are essential to be successful in the endeavor.

Teacher-mentor selection and preparation

The key role teacher-mentors in schools play in nurturing the interests and talents of science-prone students cannot be overestimated. Guidelines for the selection of teacher-mentors will highlight the need to have a passion for their subject, to be capable of sharing their passion with young people, and to demonstrate willingness to invest personal time in this endeavor. Teacher-mentors in schools will be given ample professional development opportunities to prepare them for their role. One of the components of the teacher-mentor preparation program will focus on the qualities of gifted and creative scientists and mathematicians, and how these qualities are likely to be manifested in young students gifted in these domains. Among others, this component would be important for two reasons: it would enhance teachers' effectiveness in talent-spotting, and teachers can try to inculcate and nurture some of these qualities in their young charges. Teachers will also learn about the qualities, characteristics and practices of math and science teachers whom gifted students have found to be very effective in nurturing talents in these domains: the genuine interest in the student as an individual and for his total well-being, the trust in the student's giftedness/exceptional ability, the willingness to advocate for the student; and going beyond the curriculum to create and expose interested students to opportunities that will extend, deepen, and enhance their grasp of the content and issues in the domain.

Included in the teacher-mentor preparation program will be a component on encouraging girls in science. All teachers will be aware of the research evidence that gifted girls face unique problems and perceive barriers in doing high level science courses and pursuing science careers. Beyond the general exhortation to encourage gifted girls to stay the course, teachers will learn specific strategies to counsel, guide and enthuse female students gifted in the sciences. These include frank discussions of issues unique to gifted females, and how to deal with them. Teachers will learn that gifted girls have been found to place higher values on the social/aesthetic than the theoretical in values inventories, and therefore tend to gravitate towards service-oriented careers (Gottfredson, 2005; Lubinski & Benbow, 1995, Tobin & Fox, 1980). They will discuss with students the 'social orientation' of science research and its potential to contribute to a better quality of life; help girls see that they are likely to work in a predominantly male environment, and how to hold their own in such situations; prepare them for the role conflict and overload - how to handle *both* the long hours in the research lab and at the same time fulfill the role and responsibilities of wife and mother at home; face the reality that it would be "difficult in a field that changes as rapidly as science to drop out for a number of years and then hope to return without major re-training"(McGrayne, 1993, p.355); as well as a host of other problems and issues that the research evidence shows are faced by female gifted scientists, arising from their gender (Subotnik & Arnold, 1995).

Teacher-mentors will also be provided opportunities to upgrade content knowledge in their area of specialization and/or interest. Teachers must have confidence in themselves to be able to readily undertake discussions on topics and issues beyond the curriculum; teachers must give students space and freedom to pursue interest areas in greater breadth and depth, and teachers themselves must have the exposure and experience in order to provide direction to students and suggest alternatives for their exploration. Therefore, in addition to periodic content upgrading, teachers will also be assigned professional science mentors with whom they can discuss relevant issues when the need arises.

Mentor selection and preparation

Besides the optimal selection of students, the success of the program depends equally on the mentors as the quality of the mentoring relationship and experience rests on them. An important fact to acknowledge is that mentoring is a very resource-intensive endeavor, and organizers of mentorship programs cannot assume that altruism would be a sufficient factor to attract the best for the program. A structure of incentives could be put in place in recognition of the contributions of mentors who are willing to share their expertise and time to mentor gifted young students. For instance, mentors' contributions could be reflected in tenure decisions and in the department's outreach efforts, and publicly acknowledged by the department chair. Mentors who volunteer in such programs could be given some priority when schools or the Ministry of Education seek consultancy services of the university in relevant areas of expertise. Just as outstanding mentees who achieve excellence and perform well in high level competitions are granted direct admission to the local universities without having to sit for national examinations, the mentors behind their achievement should be accordingly honored with some tangible award. Beyond recognition of contributions, potential mentors should also be aware of the tangible benefits to their own research and career to have mentees collaborate with them.

To be sure, such a system of incentives alone may succeed in attracting willing mentors, but it cannot guarantee that they would have 'suitable' qualities to make them effective mentors. Just as teachers need to be prepared for their role, so too must mentors, especially since many of them are unlikely to have experience working with younger gifted students. The issue of developmental considerations is an important one as evident in the experience of a number of the SRP students who wrote about the problem of mentors underestimating or overestimating their abilities and readiness. Prospective mentors, therefore, should be informed about the precocity of gifted students as well as their asynchronous development. The dysynchrony could be in the form of disparity in the level of intellectual prowess and maturity, or it could be in the wide gap between the theoretical and conceptual knowledge of a very well-read gifted student who does not have the practical exposure. While such a student might have the facility to grasp and conceptualize sophisticated content, he might lack the basic knowledge and skills to design and set up experiments to test his hypotheses and ideas. An effective mentor is one who is sensitive to this and is able to help the mentee bridge the gap.

As many of the mentors are likely to be male professors, the issue of gender in science will be of particular importance as they are likely to have female students among their mentees, and mentors need to be empathetic to the issues that female scientists encounter in the field and have frank discussions on what these could be, and how to overcome some of them with appropriate approaches and attitudes.

A good incentive structure coupled with a mentor-preparation program will help preempt and alleviate problems of unwilling and indifferent mentors, and ensure that those in the program are in it for the right reasons and have the necessary knowledge to enhance the success of the mentoring relationship, on which the success of the mentorship program hinges.

Mentorship in Science Program Features

Science is a hierarchical discipline. Unlike other domains like writing and music, it is rare to find prodigies in science as young children are unlikely to have mastery of the body of knowledge, concepts and skills of the discipline without some formal training (Feldman 1986; Goldsmith, 1987). For a mentorship program at the high school level to be effective, it is essential that all participants have some foundation of the knowledge and skills of science to be able to maximally benefit from the program. To be sure, many of the eligible students would probably have acquired some level of content knowledge beyond their years, through reading and learning on their own as well as extension projects in school. But they are less likely to have had the practical experience in the labs as state-of-the-art equipment and facilities are unlikely to be found in the majority of pre-tertiary institutions.

It has been shown that the majority of students in the SRP tended to come from a select small number of schools. Therefore, it would be worth mounting a program at the lower grade levels (Grades 9 - 10) that would equip science-prone students with the basic foundational and lab skills. A Science Exploration Program could be open to all interested and highly able science students in these schools who would be willing to spend some personal time exploring areas in science that fascinate them, and to find out more about what research in these areas entails. Such a feeder program could ensure a talent pool of students who would be more ready for the more demanding mentorship program at the high school level.

The structure of the mentorship research program should be sufficiently flexible as the nature of the projects in the different sciences varies widely. Broad guidelines should suffice to ensure minimal number of contact hours, but the nature of the contact, face-to-face meetings and discussions and number of lab sessions should be left to the discretion of mentors and their mentees, based on the nature and progress of their projects. Just as e-mentoring should be allowed in lieu of weekly meetings, a prolonged period of attachment to the university could be considered for mentees whose projects require close and intense monitoring of results. Such an arrangement should not be difficult especially for students in schools offering the Integrated Program where there is more leeway for schools to design programs customized to the needs of individual students.

In light of the highly positive experience of students in residential mentorship programs, including the SRP which had a residential component at one time, the ideal program would have a two or three-week stay-in component. First of all, this would give gifted science students the opportunity to live with and commingle with intellectual peers who have similar passions. The interaction with elite peers can only serve to broaden their perspectives and enhance their receptivity to diversity. Secondly, the on-campus stay can provide participants an authentic experience of what it really means to do the kind of research they have chosen. Do they have the discipline to forego leisure and fun with peers to work in the labs during the critical phase of their projects? Do they enjoy the experience or value the work enough to want to continue to make personal scarifies? Do they have what it takes to succeed in their chosen field? These are essential issues young gifted students need to confront before they make important course and career decisions. Thirdly, science is becoming more interdisciplinary in nature. It is important to create opportunities for students 'specializing' in an area to be exposed to other areas of research and development so that they see the synthetic nature of scientific research, and the possibilities of collaborative cross-field research projects.

Conclusion

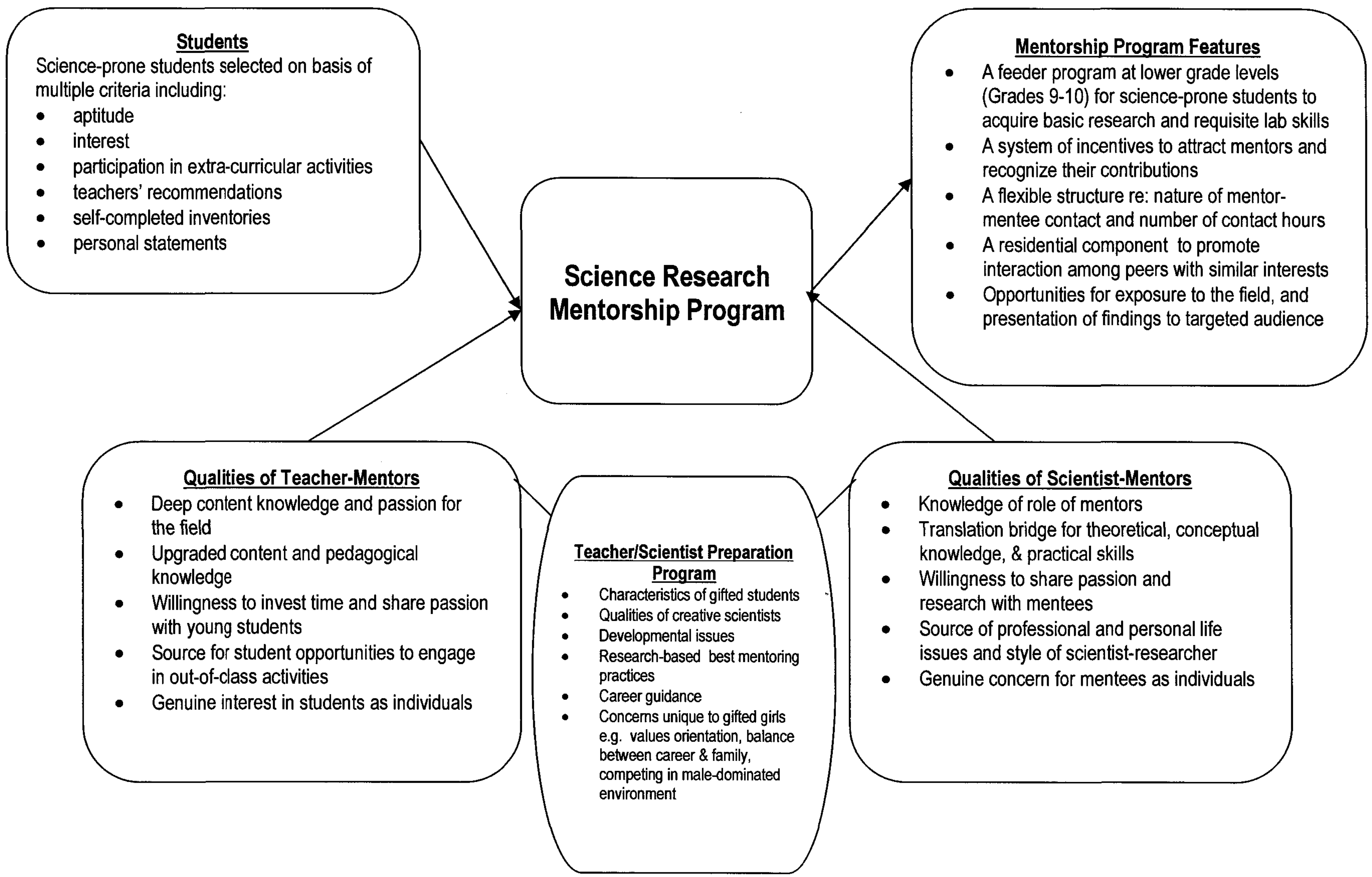
From the findings of the SRP study, there is clear evidence that there is a pool of dedicated and talented teachers and mentors who can make this ideal program work, and that many gifted science students will benefit from it. Given the government's commitment to harness resources to support Singapore's initiative to develop the country into a research and development hub for science, the burgeoning interest of schools in mentorships as a way to develop science talents as well as the increasing possibilities of synergistic partnerships between institutions of higher learning and research institutes, this ideal program can become a reality if all parties involved devote the necessary resources – financial, physical and human – to the enterprise.

A final word

According to Joseph Coates (2003), a consulting futurist, "Over the next century, there will be an indeterminately large number of advances in science and technology that will affect our personal, family, group work, organizational and governmental lives and behavior. [These changes] will…deliver unheralded and until recently unanticipated capabilities to humankind." (p.1073-74). How far Coates' description of this portentous future will come true depends on how well we develop science talent in young people.

Talent development does not happen serendipitously and cannot be left to chance. A better understanding of the scientific talent development process can help inform policy making and practice in creating a nexus among the catalysts involved and ensure that potential optimally realized can make a qualitative difference to humanity.

Figure 3: A Mentorship Program Model for Talent Development in the Sciences



References:

Adams, J. U. (2004). How to be a good mentor. *The Scientist, 18,* 56-57, August 2, 2004.

Agency for Science, Technology and Research (A*STAR) (http://www.a-star.edu.sg/astar/about/action/keyfocus.do).

Albert, R.S. (1993). *The contribution of early family history to the achievement of eminence.* Paper presented at the national research symposium on talent development, University of Iowa, Iowa City.

Albert, R.S. (1995). The achievement of eminence: A longitudinal study of exceptionally gifted boys and their families. In R. F. Subotnik & K.D. Arnold (Eds.). *Beyond Terman: Contemporary longitudinal studies of giftedness and talent.* (pp. 282-315). New Jersey: Ablex Publishing.

American heritage dictionary of the English Language (4th ed.). (2000). Boston: Houghton Mifflin.

American Physical Society (1998). *Critique of proposed California science content standards.* Retrieved on March, 18, 2005, from http://www.sci-ed-ga.org/standards/critique.html.

Arnold, K. D. (1992). Undergraduate aspirations and career outcomes of academically talented women: A discriminant analysis. *Roeper Review, 15,* 169-175.

Arnold, K.D., Noble, K.D. & Subotnik, R.F. (Eds.). (1996). Remarkable *women. Perspectives on female talent development.* NJ: Hampton Press.

Ayalon, H. (2003). Women and men go to university: Mathematical background and gender differences in choice of field in higher education. *A Journal of Research. March,* 1-20.

Balakrishnan,V. (2004). *Speech at the A*STAR scholarship award ceremony.* July 21, 2004. Retrieved on September, 1, 2004 (http://www.a-star.edu.sg/astar/speeches).

Benbow, C. & Arjmand, O. (1990). Predictors of high academic achievement in mathematics and science by mathematically talented students: A longitudinal study. *Journal of Educational Psychology, 82*, 430-441.

Benbow, C & Lubinski, D. (1993). Psychological profiles of the mathematically talented: Some sex differences and evidence supporting their biological basis. In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178.* (pp.44-66). Chichester: John Wiley & Sons.

Benbow, C. & Lubinksi, D. (1995). The study of mathematically precocious youth: The first three decades of a planned 50-year study of intellectual talent. In R. F. Subotnik & K.D. Arnold (Eds.). *Beyond Terman: Contemporary longitudinal studies of giftedness and talent.* (pp. 255-281). New Jersey: Ablex Publishing

Benbow, C., Lubinksi, D. & Sanjani, H. (1999). Our future leaders in science: Who are they and can we identify them early? In N. Colangelo & S. Assouline (Eds.), *Talent development III. Proceedings from the 1995 Henry B. and Jocelyn Wallace national research symposium on talent development.* (pp. 59-70). Scottsdale, AZ: Gifted Psychology Press Inc.

Berger, S. (1990). *Mentoring.* ERIC Clearinghouse on Disabilities and Gifted Education.

Bernstein, M., Garnier, H. & Root-Bernstein, R.S. (1995). Correlations between avocations, scientific style work habits, and professional impact of scientists. *Creativity Research Journal, 8,* 115-137

Bisland, A. (2001). Mentoring: An educational alternative for gifted students. *Gifted Child Today, 24,* 22-25, 64.

Bloom, B.S. (Ed.) (1985). *Developing talent in young people.* New York: Ballantine.

Brainard, S.G. & Carlin, L. (2001). A six-year longitudinal study of undergraduate women in engineering and science. In M. Lederman & I. Bartsch (Eds.) The *gender and science reader.* (pp. 24-37). New York: Routledge.

Brandwein, P.F. (1992). Science talent: The play of exemplar and paradigm in the science education of science-prone young. *Science Education, 76,* 121-139.

Brandwein, P.F. (1995). *Science talent in the young expressed within ecologies of achievement.* The national research center on the gifted and talented research-based decision-making series. Storrs, CT: The National Research Center on the Gifted and Talented, University of Connecticut.

Brandwein, P.F. & Passow, H. A. (1985). *Gifted young in science: Potential through performance.* Washingtong, D.C.: National Science Teachers' Association.

Callahan, C.M. (1997). The construct of talent. *Peabody Journal of Education, 72,* 21-35.

Callahan, C.M. (2002). *Advanced Placement and International Baccalaureate programs for talented students in American high schools: A focus on mathematics and science.* (RM03176). Storrs, CT: The National Research Center on the Gifted and Talented, University of Connecticut.

Casey, K. M. A., & Shore, B. M. (2000). Mentors' contributions to gifted adolescents' affective, social, and vocational development. *Roeper Review, 22*, 227-230

Casserly, P.L. (1974). Factors affecting female participation in advanced placement programs in mathematics, chemistry and physics. In L.H. Fox, L. Brody & D. Tobin (Eds.). *Women and the mathematical mystique.* (pp. 138-163). Baltimore: Johns Hopkins University Press.

Chang, A.L. (2004). New faces. More women needed in research. *Straits Times,* October 15, 2004.

Clasen, D. R. & Clasen, R.E. (2003). Mentoring: A time-honored option for education of the gifted and talented. In N. Colangelo & G.A. Davis (Eds.), *Handbook of gifted education.* (3rd edition, pp. 254-267). New York: Pearson Education Inc

Clark, B. (2002). *Growing up gifted. Developing the potential of children at home and at school.* (6th edition). Prentice Hall.

Coates, J. F. (2003). Future innovations in science and technology. In L.V. Shavininia (Ed.). *The international handbook on innovation.* (pp. 1073-1093). Elsevier Science.

Cohen, J. (1990). Things I have learned (so far). *American Psychologist, 45,* 1304-1312

Colangelo, N., Assouline, S., Chen, I. & Tsai, T. (1999). Parental involvement in the academic and social lives of academically talented elementary school students. In N. Colangelo & S. Assouline (Eds.) *Talent development: Proceedings from the 1995 H.B. and Jocelyn Wallace national research symposium on talent development* (pp. 307-313). Scottsdale, AZ: Gifted Psychology Press.

Colangelo, N. & Davis, G. (Eds.). (2003). *Handbook of gifted education. (3rd Edition).* New York: Pearson Education Inc.

Colangelo, N. & Dettmann, D. (1983). A review of research on parents and families of gifted children. *Exceptional Children, 50,* 20-27.

Colangelo, N. & Kerr, B.A. (1990). Extreme academic talent: Profiles of perfect scorers. *Journal of Educational Psychology, 82*(3), 404-409.

Committee on Science, Engineering and Public Policy [COSEPUP].(1997). *Adviser, teacher, role model and friend. On being a mentor to students in science and engineering.* Washington, D.C. National Academies Press.

Cox, C.M. (1992). The early mental traits of 300 geniuses. In R.S. Albert (1992). *Genius and Eminence.* (pp. 53-58). New York: Pergamon

Cromie W.J. (1999, May 13). Barriers to women in science discussed. *Harvard University Gazette.* Retrieved on September, 1, 2004 from *http://www.news.harvard.edu/gazette/1999/05.13/women.sci.html*

Cross, T & Coleman, L (1992). Gifted high school students' advice to science teachers. *Gifted Child Today, 15,* 25-26.

Csikszentmihalyi, M (1992). *Flow: The psychology of happiness.* London: Rider.

Csikszentmihalyi, M. (1996). The creative personality. *Psychology Today, 29*(4), 36-40.

Csikszentmihalyi, M. (1999). Creativity across the life span: A systems view. In N. Colangelo & S. Assouline (Eds.), *Talent development III. Proceedings from the 1995 Henry B. and Jocelyn Wallace national research symposium on talent* development, (pp. 9-18). Scottsdale, AZ: Gifted Psychology Press Inc.

Csikszentmihalyi, M., Rathunde, K. & Whalen, S. (1993). *Talented teenagers: The roots of success and failure.* New York: Cambridge University Press.

Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming adult. How teenagers prepare for the world of work.* New York: Basic Books.

Daloz, L.A. (1999). *Mentor: Guiding the journey of adult learners.* San Francisco: Jossey-Bass.

Davalos, R. A. & Haensly, P.A. (1997). After the dust has settled: Youth reflect on their high school mentored research experience. *Roeper Review, 19,* 204-207.

Detterman, D.K. (1993). Giftedness and intelligence: One and the same? In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178.* (pp.22-44). ChiChester: John Wiley & Sons.

Detterman, D.K., Gabriel, L.T., & Ruthsatz, J.M. (1998) Absurd environmentalism. Open peer commentary on Howe, Davidson & Sloboda: Innate talents: Reality or myth? *Behavioral and Brain Sciences, 21,* 411-412.

Eccles, J. (1985). Why doesn't Jane run? Sex differences in educational and occupational patterns. In F.D. Horowitz & M. O'Brien (Eds.), *The gifted and talented: Developmental perspectives* (pp. 251-295). Washington, DC: American Psychological Association.

Eccles, J. & Harold, R.D. (1992). Gender differences in educational and occupational patterns among the gifted. In N. Colangelo, S. Assouline & D. Ambronson (Eds.), *Talent development: Proceedings from the Henry B. and Jocelyn Wallace national research symposium on talent development.* (pp.3-29). Unionville, NY: Trillium Press.

Ellington, M.K., Haeger,W.W. & Feldhusen, J.F. (1986). The Purdue mentor program. A university-based mentorship program for G/C/T children. *Gifted Child Today, March-April,* 2-5.

Ericsson, K.A. (2003). The acquisition of expert performance as problem solving: Construction and modification of mediating mechanisms through deliberate practice. In J. E. Davidson and R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 31-83). New York: Cambridge University Press.

Ericsson, K.A., Krampe, R. Th. & Heizmann, S. (1993). Can we create gifted people? In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178.* (pp.222-249). Chichester: John Wiley & Sons.

Europe needs more scientists: EU blueprint for action, Press release, April 2, 2004. Retrieved on September 1, 2004 from http://www.innovations-report.de/html/berichte/bildung_wissenschaft/bericht-27803.html

Faranga, S.J. & Joyce, B.A. (1998). Science-related attitudes and science course selection: A study of high ability boys and girls. *Roeper Review, 20,* 247-251.

Feldman, D. H. (1991). *Nature's gambit. Child prodigies and the development of human potential.* New York: Teachers' College Press.

Feldman, D. H. & Katzir, T. (1998). Natural talents. An argument for the extremes. Open peer commentary on Howe, Davidson & Sloboda : Innate talents: Reality or myth? *Behavioral and Brain Sciences, 21,* 414.

Feldman, D. H. & Piirto, J. (1995). Parenting talented children. In I.M. Bornstein (Ed.). *Handbook of parenting (*pp.285-304). New York: Longman.

Feng, A.X. (2000). *Isolating home/school factors contributing or hindering the development of American physics Olympians.* Unpublished doctoral dissertation. St John's University, Jamaica, New York.

Fensham, P. (2000). Providing suitable content in the 'science for all' curriculum. In R. Millar, J. Leach & J. Osborne (Eds.). *Improving science education. The contributions of research.* (pp.147-164). Buckingham: Open University Press.

Fleener, K. & Bucher, K. (2003). Linking reading, science and fiction books. *Childhood Education, 80,* 76-82.

Fleming, E.S. & Hollinger, C.L. (1995). Project Choice: A longitudinal study of the career development of gifted and talented young women. In R. F. Subotnik & K.D. Arnold (Eds.). *Beyond Terman: Contemporary longitudinal studies of giftedness and talent.* (pp. 316-348). New Jersey: Ablex Publishing.

Fox, L.H., Sadker, D. & Engel, J.L. (1999). Sexism in the schools: Implications for the education of gifted girls. *Gifted and Talented International, 19, 66-91.*

Freeman, J. (1998). Inborn talent exists. Open peer commentary on Howe, Davidson & Sloboda : Innate talents: Reality or myth? *Behavioral and Brain Sciences, 21,* 415.

Freeman, J. (2004). Cultural differences on gifted gender achievement. *High Ability Studies, 15,* 7-23.

Friedler, Y. & Tamir, S. (1990). Sex differences in science education in Israel: An analysis of 15 years of research. *Research in Science and Technology Education, 8,* 21-34.

Fu, V.R. (2005). *The issues. Learning and teaching in preschool.* PBS teacher source. Retrieved on March 15, 2005 from http://www. pbs.org.teachersource/prek12/issues/303.issues.htm

Gagne, F. (2003). Transforming gifts into talents: The DMGT as a developmental theory. In N. Colangelo & G. Davis (Eds). *Handbook of gifted education.* (3rd edition, pp. 60-74). New York: Pearson Education Inc.

Gagne, F. (2004). Transforming gifts into talents: The DMGT as a developmental theory. *High Ability Studies, 15,* 119-147.

Gall, M.D., Gall, J.P. & Borg, W. (2003). *Educational research. An introduction.* Boston: Allyn & Bacon.

Gardner, H. (1997). *Extraordinary minds: Portraits of exceptional individuals and an examination of our extraordinariness.* New York: Basic Books.

Ginsburg, H,. Blafanz, R., & Greenes, C. (1998). Challenging mathematics for children. In A. Costa (Ed.). *Teaching for intelligence II.* (pp. 6-12) Arlington Heights, IL: Skylight.

Glass, L. W. (1996). Gifted youth: A challenge for science education. In C. Benbow & D.Lubinski (Eds). *Intellectual talent: Psychometric and social issues.* (pp. 159-168). Baltimore, MD, US: Johns Hopkins University Press.

Goh, K.C. & Atputhasamy, L (2001). *Teacher education in Singapore: What motivates students to choose teaching as a career?* Paper presented at the International Educational Research Conference, University of Notre Dame, Fremantle, Western Australia, December 2-6, 2001.

Goldsmith, L.T. (1987). Girl prodigies. Some evidence and some speculations. *Roeper Review, 10,* 74-82.

Gottfredson, L. S. (1999). Special Issue - Intelligence and social policy," *Intelligence*, 24, (1), January - February 1997.

Gottfredson, L. S. "What's holding women back in science?" Wrong question. Presentation in the panel "Women in science: Are they being held back?" sponsored by The Ensemble Studio Theatre and The Alfred P. Sloan Foundation in association with The New York Academy of Sciences Women Investigators Network, Cooper Union, New York City, April 14, 2005. Retrieved on May 15, 2005 from http://www.udel.edu/educ/gottfredson/reprints/

Goyette, K., & Xie, Y. (1999). Educational expectations of Asian American youths: Determinants and ethnic differences. *Sociology of Education, 72,* 22-36.

Gross, M. (2004). *Exceptionally gifted children* (2nd ed.). London: Routledge Falmer.

Grossman, J (2002). America must invest more human capital in scientific, technical fields, *OpEd. The National Academies,* October 11, 2002.

Gruber, H (1998). The social construction of extraordinary selves: Collaboration among unique creative people. In. R. C. Friedman & K.B. Rogers (Eds.). *Talent in context. Historical and social perspectives on giftedness.* (pp.127-148). Washington D.C.: American Psychological Association.

Han, M. (personal communication, August 24, 2004)

Heller, K. (1993). Scientific ability. In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178* (pp.139-159). Chichester: John Wiley & Sons.

Hoover-Dempsey, K.V. & Sandler, H.M. (1995). Parental involvement in children's education. Why does it make a difference? *Teachers' College Record, 97,* 2, Winter 1995.

Hoover-Dempsey, K.V. & Sandler, H.M. (1997). Why do parents become involved in their children's education? *Review of Educational Research*, 67(1), 3-42.

Howe, M.J. (1993). The early lives of child prodigies. In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178.* (pp.85-105). Chichester: John Wiley & Sons.

Howe, M.J. (1999). *Genius explained.* Cambridge: Cambridge University Press

Howe, M.J., Davidson, J.W. Sloboda, J.A. (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences, 21,* 399-407.

Hyde, J. & Kling, K. (2001). Women, motivation and achievement. *Psychology of Women Quarterly, 25,* 264-378.

Imbrosciano, A. & Berlach,R. (2003) Teacher perceptions of the relationships between intelligence, student behavior, and academic performance. *Issues in Educational Research, 13.* 1-12.

Innamorato, G. (1998). Creativity in the development of scientific giftedness Educational implications. *Roeper Review, 21,* 54-59.

Inzlicht, M. & Ben-Zeev, T. (2003). Do high-achieving female students underperfom in private? The implications of threatening environments on intellectual processing. *Journal of Educational Psychology, 95,* 796-805.

Jacobs, J. E. & Weisz, V. (1994). Gender stereotypes: Implications for gifted education. *Roeper Review. 16,* 152-155

Jarwan, F. & Feldhusen, J. (1993). *Residential schools of mathematics and science for academically talented youth: An analysis of admission programs.* Storrs, CT: The National Research Center on the Gifted and Talented, University of Connecticut.

Jenkins, E. (2000). 'Science for all': time for a paradigm shift? . In R. Millar, J. Leach & J. Osborne (Eds.). *Improving science education. The contributions of research.* (pp.207-226). Buckingham: Open University Press.

Jenson, A. (1996). Giftedness and genius: Crucial differences. In C.P. Benbow & D. Lubinski (Eds.). *Intellectual talent. Psychometric and social issues.* (pp. 393-413). Baltimore: Johns Hopkins University Press.

Kay, S. (2002). An interview with Abraham J. Tannenbaum: Innovative programs for the gifted and talented. *Roeper Review, 24,* 186-190.

Kaufmann, F. (1981). The 1964-1968 Presidential scholars. A follow-up study. *Exceptional Children, 48,* 164-169.

Kaufmann, F. (2000). Gifted education and the romance of passion. *Gifted Child Today.*

Kerr, B. A. (1997) *Smart girls: A new psychology of girls, women, and giftedness.* Phoenix, AZ: *Gifted Psychology.*

Kerr, B. & Nicpon, M. (2003). Gender and giftedness. In N. Colangelo & G. Davis (Eds.). *Handbook of gifted education.* (3rd edition, pp. 493-505). New York: Pearson Education Inc.

Lane, N. (1999). *Why are there so few women in science? Nature Debates, September, 1999.* Retrieved on June 1, 2004 from http://www.nature.com/nature/debates/women/women_contents.html

Latzke, J. (2004, January 16). Study: Few women, minorities getting professorships in science and engineering. *Associated Press.* Retrieved April 19, 2004 from http://hosted.ap.org

Le Maistre, C. & Kanevsky, L. (1997). Factors influencing the realization of exceptional mathematical ability in girls: an analysis of the research. *High Ability Studies, 8,* 31-46.

Lee, L. (2004, September 18). 1000 students to 'cut' classes to research at Biopolis Lab. *Straits Times.* Retrieved September 18, 2004 from http://asiaone.com.sg

Lewin, T. (2004, January 15). Despite gain in progress, women lag in tenure in 2 main fields. *New York Times.* Retrieved April 19, 2004 from http://www.nytimes.com

Long, S. (1990). The origins of sex differences in science. *Social Issues, 68,* 1297-1315.

Lorenz, E.H. & Lupart, J.L. (2001). *Gender differences in math, English and science for grade 7 and 10 students – expectations for success.* Paper presented at the Canadian Society for Studies in Education, Quebec, Canada, May 25, 2001.

Lubinksi, D. & Benbow, C. (1995). The study of mathematically precocious youth: The first three decades of a planned 50-year study of intellectual talent. In R. F. Subotnik & K.D. Arnold (Eds.). *Beyond Terman: Contemporary longitudinal studies of giftedness and talent.* (pp. 255-281). New Jersey: Ablex Publishing

Lubinksi, D, Benbow, C & Morelock, M (2002). Gender differences in engineering and the physical sciences among the gifted: An inorganic-organic distinction. In K.Heller, F. Monks, R.Sternberg & R.Subotnik (Eds.), *International handbook of giftedness and talent.* (2nd edition, pp.633-648). Oxford, UK: Pergamon.

Luman, S. (2004). Singapore wants you. The future-friendly city-state has an offer bioscientists can't refuse: unrestricted research, top-notch equipment, and limitless funds. (Just leave your chewing gum at home.) *Wired magazine. 12* (8). August 2004.

Marland, S. (1972). *Education of the gifted and talented. Report to the Congress of the United States by the U.S. Commissioner of Education*. Washington, DC: U.S. Government Printing Office.

Marshall, C. & Rossman G.B. (1995). *Designing qualitative research. (2nd edition).* (pp. 120 to 141). London: Sage Publications

McBer, H. (2000). Research into teacher effectiveness: A model of teacher effectiveness. Research Report 216, Department for Education and Employment, England.

McGrayne, S.B. (1992). *Nobel prize women in science. Their lives, struggles and momentous discoveries.* New York: Birch Lane Press.

Milgram, R. & Hong, E. (1998). Family influences on the realization of scientific giftedness in Israeli adolescents: A follow-up study after 13 years. In U.P. Gielen & A.L. Comunian (Eds.). *The family and family therapy in international perspective.* (pp. 484-503). Trieste, Lint.

Milgram, R. & Hong, E. (1999). Creative out-of-school activities in intellectually gifted adolescents as predictors of their life accomplishment in young adults: A longitudinal study. *Creativity Research Journal, 12,* 78-89.

Miller, K., Steiner, S. F., & Larson, C. D. (1996). Strategies for science learning. *Science and Children, 33*(6), 24-27.

Ministry of Education (1997). *Science research program. The first ten years.* A commemorative issue, 1988-1997.

Ministry of Education (2003). *Education Statistics Digest 2003.* Retrieved on March 1, 2005 from http://www.moe.gov.sg/esd/Factsheet2004.pdf

Ministry of Education (2004). http:www.moe.edu.sg

Monsaas, J.A. & Engelhard, G. (1992). Home environment and the competitiveness of highly accomplished individuals in four talent fields. In R.S. Albert (1992). *Genius and eminence.* (pp. 253-265). New York: Pergamon.

Moon, S., Jurich, J. & Feldhusen, J. (1998). Families of gifted children: Cradles of development. In R. C. Friedman & K. B. Rogers (Eds.), *Talent in context* (pp. 81-99). Washington, DC: American Psychological Association.

Moss, B. & Hendershot, J. (2002). Exploring sixth graders' selection of nonfiction trade books: When students are given the opportunity to select nonfiction books, motivation for reading improves. *The Reading Teacher, 56,* (1), 6- 17

Mullis, I., Martin, M., Gonzalez, J. & Chrostowski, S. (2004). *TIMSS 2003 International Math Report.* Boston College: TIMSS & PIRLS International Study Center.

Nakagawa, S. (2004). A farewell to Bonferroni: The problems of low statistical power and publication bias. *Behavioral Ecology, 15,* (6), 1044-1045.

National Research Council (2002). *Learning and understanding. Improving advanced study of mathematics and science in U.S. high schools.* Washington, D.C. National Academy Press.

National Science Board (2003). *The science and engineering workforce. Realizing America's potential.* Washington, D.C. National Academies Press. Retrieved April 22, 2004 from http://www.nsf.gov/nsb/documents/2003/nsb0369/nsb0369.pdf

Newton, R.R. & Rudestam, K.E. (1999). *Your statistical consultant. Answers to your data analysis questions.* (pp. 227-237). Thousand Oaks, CA: Sage.

Nokelainen, P, Tirri, K, Campbell, J.R. & Walberg, H (2004). Isolating factors that contribute or hinder adult productivity: Comparing the Terman longitudinal studies with retrospective Olympiad studies. In J. R. Campbell, K. Tirri, P. Ruohotie & H. Walberg (Eds.). *Cross-cultural research: Basic issues, dilemmas, and strategies.* (pp.119-139). Finland: Research Center for Vocational education, University of Tampere.

Olszewski-Kubilius, P. (2001). Parenting practices that promote talent development, creativity, and optimal adjustment. In M. Neihart, S. Reis, S., N. Robinson, & S. Moon (Eds.), *The social and emotional development of gifted children. What do we know?* (pp.205-212). Waco, TX: Prufrock Press.

Olszewski-Kubilius, P & Kulieke, M. (1989). Personality dimensions of gifted adolescents. In J. VanTassel-Baska, & P. Olszewski-Kubilius (Eds.), *Patterns of influence on gifted learners: The home, the self and the school.* (pp. 125-145). New York: Teachers College Press.

Olszewski-Kubilius, P., & Lee, S. (2004). The role of participation in in-school and out-of-school activities in the talent development of gifted students. *Journal of Secondary Gifted Education, 15,* 107-124.

Olszewski-Kubilius, P. & Yasumoto, J. (1994). Factors affecting the academic choices of academically talented adolescents. *Talent development, Volume II* (pp. 393-398) Ohio Psychology Press.

Overington, M. (1977). The scientific community as audience: Toward a rhetorical analysis of science. *Philosophy and Rhetoric. 10.* 145.

Piechowski, M. (1999). Personal strengths and chance factors in co-incidence. In N. Colangelo & S Assouline (Eds.), *Talent development III. Proceedings from the 1995 Henry B. and Jocelyn Wallace national research symposium on talent development.* (pp. 335-352). Scottsdale, AZ: Gifted Psychology Press Inc.

Pleiss, M. K., & Feldhusen, J. F. (1995). Mentors, role models, and heroes in the lives of gifted children. *Educational Psychologist, 30*, 159-169.

Plucker, J.A. & Stocking, V.B. (2001). Looking outside and inside: Self-concept development of gifted adolescents. *Exceptional Children. 67,* 535-548.

Preston, A.E. (2004). *Leaving science. Occupational exit from scientific careers.* New York: Russell Sage Foundation.

Purcell, J., Renzulli, J. McCoach, N. & Spottiswoode, H. (2002). The magic of mentorship. *Parenting for High Potential,* December, 22-26.

Pyryt, M. (2000). Talent development in science and technology. In K. Heller, F. J. Monks, R. Sternberg & R. Subotnik (Eds.). *International handbook on giftedness and talent.* (2nd edition, pp. 427-438). Oxford, UK: Elsevier Science.

Reis, S. (2003). Gifted girls, twenty-five years later: Hopes realized and new challenges found. *Roeper Review, 25,* 154-157

Reis, S. & Park, S. (2001). Gender differences in high-achieving students in math and science. *Journal of Education for the Gifted, 25,* 52-74.

Root-Bernstein, R. & Root-Bernstein, M. (2003). Intuitive tools for innovative thinking. In L.V. Shavininia (Ed.). *The international handbook on innovation.* (pp. 377-387). Elsevier Science.

Rossiter, S.V. (2004). *The science glass ceiling. Academic women scientists and the struggle to succeed.* New York: Routledge.

Rossman, G.B. & Rallis, S.F. (2003). *Learning in the field. An introduction to qualitative research.* (2^{nd} edition, pp. 267-308). London: Sage Publications.

Rowan,B., Chiang, E. & Miller, R. (1997). Using research on employees' performance to study the effects of teachers on students' achievement. *Sociology of Education, 70,* 256-284.

Seymour, E. & Hewitt, N.M. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview Press.

Schatz, E. (1999). Mentors: Match making for young people. *Journal of Secondary Gifted Education, 11,* 67-86.

Schwarz, N. (1999). Self reports: How the question shapes the answers. *American Psychologist, 54* (2), 93-105.

Shanmugaratnam, T. (2005). *FY 2005 Committee of Supply debate. Reply by Minister for Education on school sector.* March, 9, 2005. Retrieved on April 12, 2005 from http:www.moe.gov.sg/parliamentary_replies/2005/09032005.htm

Shavinina, L.V. (2004). Explaining high abilities of Nobel laureates. *High Ability Studies (15),* 243-254.

Siegle, D. and Reis, S. (1998) Gender differences in teacher and student perceptions of gifted students' ability and effort. *Gifted Child Quarterly, 42,* 39-47.

Silverman, L.K. (1989). Career counseling for the gifted. In J. VanTassel-Baska & P. Kubilius-Olszewski, (Eds.).(1989). *Patterns of influence on gifted learners: The home, the self and the school.* (pp. 201-213). New York: Teachers College Press.

Simonton, D.K. (1988). *Scientific genius. A psychology of science.* New York: Cambridge University Press.

Simonton, D.K. (1998). Gifted child, genius adult: Three life-span developmental perspectives. In. R. C. Friedman & K.B. Rogers (Eds.). *Talent in context. Historical and social perspectives on giftedness.* (pp. 151-176). Washington D.C.: American Psychological Association.

Simonton, D.K. (1999). *Origins of genius. Darwinian perspectives on creativity.* New York: Oxford University Press.

Simonton, D.K. (2000). Genius and giftedness: Same or different. In K. Heller, F.J. Monks, R. Sternberg & R Subotnik (Eds.). *International handbook of research and development on giftedness and talent.* (2nd edition, pp. 111-122). Oxford, UK: Pergamon.

Simonton, D.K. (2003). When does giftedness become genius? And when not? In N. Colangelo & G. Davis (Eds.). *Handbook of gifted education.* (3rd edition, pp. 358-370). New York: Pearson Education Inc.

Simonton, D. K. (2004). *Creativity in science. Chance, logic, genius and zeitgeist.* MA: Cambridge University Press.

Soh, K.C. (1989). *Motives for teaching of female Certificate-in-Education students.* Institute of Education: Research Papers ERU/9/89, 1989.

Soh , K. C. (1998). Who has come to teach and why? A cross sectional comparison of four 'generations' of teaching in Singapore. *Journal of Applied Research in Education, 2,* 19-34.

Sosniak, L. (2003). Developing talent: Time, task and context. In N. Colangelo & G. Davis (Eds.). *Handbook of gifted education.* (3rd edition, pp.247-252). New York: Pearson Education Inc.

Stanley, J.C. (1993). Boys and girls who reason well mathematically. In G. Bock, & K. Ackrill (Eds.), *The origins and development of high ability - Symposium No. 178.* (pp.119-138). Chichester: John Wiley & Sons.

Stanley, J.C., Stumpf, H. & Cohn, S. J. (1999). Ipsative evaluative attitudes versus vocational interests and cognitive abilities of bright male and female seventh graders. In N. Colangelo & S. Assouline (Eds.), *Talent Development III. Proceedings from the 1995 Henry B. and Jocelyn Wallace national research symposium on talent development,* (pp. 41-58), Scottsdale, AZ: Gifted Psychology Press Inc.

Sternberg, R. & Davidson, J. (1985). Cognitive development in the gifted and talented. In F.D. Horowitz & M. O'Brien (1985). *The gifted and talented. Developmental perspectives.* (pp.37-74). Washington D.C. American Psychological Association.

Stronge, J. H. (2002). *Qualities of effective teachers.* Association for Supervision, Curriculum and Development. Alexandria, VA.

Stumpf, F. & Stanley, J. (1996). Gender-related differences on the College Board Advanced Placement and Achievement tests 1982-1992. *Journal of Educational Psychology, 87,* 353-364

Subotnik, R.F. & Arnold, K.D. (1995). Passing through the gates: Career establishment of talented women scientists. *Roeper Review, 18,* 55-61.

Subotnik, R.F. & Olzewski-Kubilius, P. (1997). Distinctions between children's and adult's experiences of giftedness. *The Peabody Journal of Education, 72,* (3&4), 101-116.

Subotnik, R.F., Olzewski-Kubilius, P. & Arnold, K. (2003). Beyond Bloom. In J. Borland (Ed). *Rethinking gifted education.* (pp. 227-238) New York: Teachers' College Press.

Subotnik, R.F. & Steiner, C.L. (1992). Adult manifestations of adolescent talent in science. *Roeper Review, 15,* 164-169.

Subotnik, R.F. & Steiner, C.L. (1995). Adult manifestations of adolescent talent in science. A longitudinal study of 1983 Westinghouse Science Talent Search winners. In R. F. Subotnik & K.D. Arnold (Eds.), *Beyond Terman: Contemporary longitudinal studies of giftedness and talent.* (pp.52-76). New Jersey: Ablex Publishing.

Subotnik, R.F., Stone, K.M. & Steiner, C. (2001). Lost generation of elite talent in science. *Journal of Secondary Gifted Education, 13* (1), 33-43.

Swiatek, M. & Lupkowski-Shoplik, A. (2000). Gender differences in academic attitudes among elementary gifted school students. *Journal for the Education of the Gifted, 23,* 360-377.

Tan, T.C. (personal communication, February 1, 2005).

Tannenbaum, A.J. (1983). *Gifted children. Psychological and educational perspectives.* New York: Macmillan.

Tannenbaum, A.J. (1996). The IQ controversy and the gifted. In C.P. Benbow & D. Lubinski (Eds.). *Intellectual talent. Psychometric and social issues.* (pp. 44-78). Baltimore: Johns Hopkins University Press.

Tannenbaum, A.J. (2003). Nature and nurture of giftedness. In N. Colangelo & G. Davis (Eds.). *Handbook of gifted education.* (3rd edition, pp. 45-59). New York: Pearson Education Inc.

Templin, M.A. (1999). A locally based science mentorship program for high achieving students: Unearthing issues that influence affective outcomes. *School Science and Mathematics,* 99, 205-212.

Tobin, D. & Fox, L.H. (1980). Career interests and career education: A key to change. In L.H. Fox, L. Brody & D. Tobin (Eds.). *Women and the mathematical mystique.* (pp. 179-192). Baltimore: Johns Hopkins University Press.

Treffinger, D. (1998). From gifted education to programming for talent development. *Phi Delta Kappan,* June, 752-755.

VanTassel-Baska, J. (1989a). Profiles of precocity. A three-year study of talented adolescents. In J. VanTassel-Baska & P. Olszewski-Kubilius (Eds.), *Patterns of influence on gifted learners: The home, the self and the school.* (pp. 29-39). New York: Teachers College Press.

VanTassel-Baska, J. (1989b). Characteristics of the developmental path of eminent and gifted adults. In J. VanTassel-Baska, & P. Olszewski-Kubilius (Eds.), Patterns *of influence on gifted learners: The home, the self and the school.* (pp. 146-162). New York: Teachers College Press.

Van Tassel-Baska, J. (1992). Educational decision making on acceleration and grouping. *Gifted Child Quarterly, 36. 187-191.*

VanTassel-Baska, J. (1998). Counseling the gifted. In J.F. Feldhusen, J. VanTassel-Baska, & K. Seeley (Eds.). *Excellence in educating the gifted.* (pp.489-510). Denver, CO: Love Publishing.

VanTassel-Baska, J. (2001). The role of Advanced Placement in talent development. *Journal of Secondary Gifted Education, 12,* 126-132.

Veltman, M.J.G. (2004). *Some simple facts.* Speech at conference on human resources, Brussels, April 2, 2004. Retrieved May 15, 2004 from http://europa.eu.int/comm/research/conferences/2004/sciprof/pdf/veltman.pdf

Walberg, H.J., Williams, D.B. & Zeiser, S. (2003). *Talent, accomplishment, and eminence.* In N. Colangelo & G. Davis (Eds.). *Handbook of gifted education.* (3rd edition, pp. 350-357). New York: Pearson Education Inc.

Webb, R., Lubinksi, D. & Benbow, C. (2002). Mathematically facile adolescents with math/science aspirations: New perspectives on their educational and vocational development. *Journal of Educational Psychology, 94,* 785-794

Whalen, S. P. (1998). Flow and the engagement of talent: Implications for secondary schooling. *National Association of Secondary School Principals (NASSP) Bulletin. Education for the gifted and talented. Finding talent in the quiet places.* February.

Winerip, M. (2005). Want to be an Intel finalist? You need the right mentor. *New York Times,* March 9, 2005.

Wu, W. & Chen, D. (2001). A follow-up study of Taiwan physics and chemistry Olympians: The role of environmental influences in talent development. *Gifted and Talented International, 16,* 16-26.

Zorman, R. (1996). The long and winding road from promise to fulfillment in science among gifted females in Israel. *High Ability Studies, 7,* 39-50.

Zuckerman, H. (1992). The scientific elite: Nobel laureates' mutual influences. In R.S. Albert (1992). *Genius and Eminence.* (pp. 157-170). New York: Pergamon.

Please rate the content validity of this survey questionnaire using the following rubric.

Part/Questions	**Areas of interest**	**Highly appropriate to probe area of interest (3)**	**Reasonably appropriate To probe area of interest (2)**	**Somewhat appropriate to probe area of interest (1)**
II(i) Q1to 15	Factors influencing science interest			
(ii) 16 & 17	Personal traits associated with science pone people			
III Q18 to 30	Reasons for joining SRP			
Q31 to 38	Impact of SRP			
Q39 to 43	Perceptions about SRP			
IV	Course taking and career decisions			
Q44.to 50	Staying in science			
Q52. to 59	Opting out of science			
Q60 to 65	Choosing a science career			
Q66. to 72	Choosing a non science career			
Q73 to 79	Leaving a science career			
V Q81 to 85	Role of teachers/school			
VI Q86	Personal values & beliefs about work, success			
VII Q87	Parental influence			
VIII	Career			
Q88	View about present work			
Q89	Changes and how these could have impacted/ will impact career decisions			

Content validity Table

Part/Questions	Areas of interest	Average rating
II(i) Q1to 15	Factors influencing science interest	2.7
(ii) 16 & 17	Personal traits associated with science pone people	3
III Q18 to 30	Reasons for joining SRP	3
Q31 to 38	Impact of SRP	3
Q39 to 43	Perceptions about SRP	2.7
IV	Course taking and career decisions	
Q44.to 50	Staying in science	3
Q52. to 59	Opting out of science	2.3
Q60 to 65	Choosing a science career	2.7
Q66. to 72	Choosing a non science career	2.7
Q73 to 79	Leaving a science career	2.3
V Q81 to 85	Role of teachers/school	3
VI Q86	Personal values & beliefs about work, success	3
VII Q87	Parental influence	3
VIII	Career	3
Q88	View about present work	3
Q89	Changes and how these could have impacted/ will impact career decisions	3
Overall		**2.85**

Student Survey: *Factors contributing to the talent development of high ability science students*

Thank you for taking the time to participate in this study. Before you begin, please note the following:

1. Not every section of the survey will apply to you. It should take you about 45 to 60 minutes to complete it. Please try to answer all the questions that apply to you.

2. If you prefer to send us your resume or curriculum vita, you may skip those questions that pertain to information in your resume/vita.

3. For the purpose of this study, this is how math/science and non-math/non science courses and occupations have been classified. **Please indicate in the table the (university) course and career category that apply to you.**

Courses: Careers:

Math/science	**Non-math/non science**	**Math/science**	**Non-math/non science**
Engineering	Business/economics	Engineering	Management
Biological science	Social science	Computer science	Lawyer
Chemistry	Arts	Doctor /dentist/vet/ophthalmologist/pharmacist	Teacher/ principal
Computational science	Education	Professor (math/science)	Social service
Material science	Mass communication		Entrepreneurs
Physics	Languages		Finance
Math	Political science		Military
Pharmacy	Philosophy		
Life sciences	Law		
Medicine			

4. Please indicate if you wish to receive a copy of the findings. Yes/No

5. For every survey that is completed, a $2 donation will be made to the Children's Cancer Foundation. (www.ccf.org.sg)

6. Thank you for participating in this important study. Please email completed survey to cgquek@wm.edu. or return it in the self-addressed envelope.

THIS PROJECT WAS FOUND TO COMPLY WITH APPROPRIATE ETHICAL STANDARDS AND WAS EXEMPTED FROM THE NEED FOR FORMAL REVIEW BY THE COLLEGE OF WILLIAM AND MARY PROTECTION OF HUMAN SUBJECTS COMMITTEE (PHONE: 757-221-3901) ON OCTOBER 27, 2004 AND EXPIRES ON OCTOBER 26, 2005.

Factors contributing to the talent development of high ability science students

PART I: Demographics
Some information about me:

Name: ______________________	Sex: M/F	
Date of Birth: __________________ Nationality: __________________ Current marital status: ___________	Ethnicity: Chinese Malay Indian Eurasian Other	
Name of Secondary School: ______ "A" level subjects & Grades	Name of Junior College: ____	

Subject	Grade	Favorite Subject (Check one)	"S" papers (Check all that apply)
Math C			
Math F			
Biology			
Chemistry			
Physics			
Computer Science			
Other:			

Programs/Competitions I have participated in: *(Check all that apply)*

Academic Olympiads (math, biology, physics, chemistry, IT)	___	Music competitions	___
Singapore Science & Engineering Fair	____	Writing competitions	___
Math competitions	___	Science competitions	___
Computer competitions	___	National Science Talent Search	___
Others: ____			
Co-Curricular Activities: ____			
____			

Achievements: (Scholarships, Academic & non-academic Awards, publications):

____

____

My position in the family: *I am the ________child in the family of ____children*
(1^{st}, 2^{nd}, 3^{rd}, 4^{th}, etc.)

Family Background

Please give us some information about your family

Information on Parents

Father	**Mother**
Nationality:	Nationality:
Race:	Race:

Father's education	**Mother's education**
a. Less than Junior College	a. Less than Junior College
b. Junior College	b. Junior College
c. Vocational School	c. Vocational School
d. Polytechnics	d. Polytechnics
e. University graduate	e. University graduate
f. Post-Graduate (Master's, Doctorate, professional degree)	f. Post-Graduate (Master's, Doctorate, professional degree)

*Choose the job that best describes your **father's** occupation*	*Choose the job that best describes your **mother's** occupation*
__Unemployed, retired	*__Unemployed, retired*
__Laborer	*__Laborer*
__Factory/construction worker	*__Factory/construction worker*
__Driver (taxi, truck, bus, delivery)	*__Driver (taxi, truck, bus, delivery)*
__Food services/restaurant	*__Food services/restaurant*
__Skilled craftsman (electrician/plumber)	*__Skilled craftsman (electrician/plumber)*
__Retail sales, clerical, customer service	*__Retail sales, clerical, customer service*
__Service technician (appliances, car, computer)	*__Service technician (appliances, car, computer)*
__Bookkeeping, accounting, related administrative	*__Bookkeeping, accounting, related administrative*
__Singer/musician/artist/writer/actor	*__Singer/musician/artist/writer/actor*
__Real estate/insurance agents	*__Real estate/insurance agents*
__Public service, social service, governmental	*__Public service, social service, governmental*
__Military/police	*__Military/police*
__Teacher, nurse	*__Teacher, nurse*
__Professional/ executive	*__Professional/ executive*
__Self employed	*__Self employed*

Total Annual Household Income

a. < $22,000	g. Between $72,001 & $82,000
b. Between $22,001 & $32,000	h. Between $82,001 & $92,000
c. Between $32,001 & $42,000	i. Between $92,001 & $102,000
d. Between $42,001 & $52,000	j. Between $102,001 & $112,000
e. Between $52,001 & $62,000	k. Between $112,001 & $122,000
f. Between $62,001 & $72,000	l. > $122,000

Throughout the questionnaire, where appropriate, please respond to the items with your ***favorite math/science subject*** in mind (i.e. the subject you indicated as your favorite in Section 1)

Part II(i). Factors contributing to my interest in science

*For each of the following items, use the scale below to indicate the extent to which you agree that the factors contributed to your interest in **math/science**.*

SA	A	D	SD
Strongly Agree	Agree	Disagree	Strongly Disagree

	SA	A	D	SD
1. Stimulating lessons in school				
2. Encouraging teachers				
3. Inspiring role models (e.g. teacher or parent passionate about science)				
4. Availability of resources in school				
5. Enrichment opportunities in school				
6. Good grades in science				
7. Peers with similar interest				
8. Co-curricular activities in school (e.g. Science club)				
9. Parents work in science field				
10. Parental influence				
11. Freedom to explore my own interests				
12. Presence of non fiction and science-related resources in the home (e.g. books, journals, CD Roms)				
13. Leisure time with family				
14. Influence of siblings				
15. Enrolment in special programs that emphasized science learning				

Part II(ii). Personal traits

16. Indicate with a (/) the items that describe you in your childhood and early adolescence:

	Curious about how things work	Enjoy discussions with intellectual peers	
	Like to tinker with things	Always questioning how things work	
	Enjoy jigsaw puzzles	Independent learner	
	Good at seeing patterns	Sense of destiny	
	Interest in current affairs	Would like to contribute to society	
	Love to collect things	Dissatisfaction with present explanations of phenomena	
	Enjoy the outdoors	Interested in new scientific developments	
	Observant about nature	Love to study design	
	Fascination with numbers	Enjoy problem solving	
	Learn things very quickly	Persistent	
	Work hard at something I like	Enjoy the arts and aesthetics	
	Enjoy solitary activity	Aspire to get a university degree	
	Strong spatial ability	Intuitive	
	Love to experiment	Love reading non fiction	
	Competitive	Other: ______________	

17. What three characteristics do you feel are most essential to be a successful scientist?

______________________, ____________________________, ________________________

Part III: Science Research Program-specific questions

Reasons for joining Science Research Program

Indicate the extent to which you agree with each of the following reasons for being a part of SRP.

SA	A	D	SD
Strongly Agree	Agree	Disagree	Strongly Disagree

	SA	A	D	SD
18. To observe scientists/researchers at work.				
19. To be able to research an area of interest in depth.				
20. To find out what scientific research is.				
21. To follow up on teachers' encouragement.				
22. To satisfy parents' desire to have me participate.				
23. To respond to my peer group.				
24. To benefit from the prestige of the program.				
25. To improve chances of getting a scholarship to university.				
26. To have access to university labs and state of the art facilities.				
27. To respond to a sibling who had been a participant who encouraged me.				
28. To see if I have what it takes to be a scientist/researcher.				
29. To get a glimpse of the life of a scientist.				
30. To have a mentor to discuss my interests with.				

Impact of the SRP

Indicate the extent to which you agree with each of the following aspects of the SRP impacted you.

SA	A	D	SD
Strongly Agree	Agree	Disagree	Strongly Disagree

	SA	A	D	SD
31. SRP further stimulated my interest in science.				
32. SRP affirmed my interest in science research.				
33. SRP deepened my knowledge beyond what the school curriculum could offer.				
34. SRP sharpened my scientific investigative skills.				
35. SRP exposed me to different career possibilities in science.				
36. Strengthened my resolve to pursue science at university level.				
37. SRP made me surer that I want(ed) to pursue a career in science.				

38a. What was **most** valuable about your SRP experience?

____

____

____

38b. What was **least** valuable about your SRP experience?

____

____

____

38c. What was **most enjoyable** about your SRP experience?

____

____

38d. What was **least enjoyable** about your SRP experience?

____

____

Perceptions of SRP

Indicate the extent to which you agree with each of the following statements about participation in SRP.

	SA	A	D	SD
39. The process of doing research was more important than the end product.				
40. I had ample time to complete my project.				
41. The program gave me the opportunity to interact with peers with similar interests.				
42. My mentor				
a. taught me skills in scientific research				
b. exemplified the qualities of a scientist				
c. was passionate about his/her work				
d. cared for me as an individual				
e. was an excellent role model				
f. inspired me to consider a career in science research				

43. Choose *the* ***three*** *most essential qualities of an effective science* mentor, *and rank them 1,2 and 3(with* ***1*** *being MOST essential and* ***3*** *being LEAST essential)*

	Well versed in his/her field	Passion for the subject	
	Genuine interest in mentee as an individual	Creates opportunities to give mentee more exposure in the field	
	Willingness to discuss his/her research with mentee	Open to divergent ideas	
	Helps mentee take risks	Plans the program according to needs of mentee	
	Knows when to help and when to let mentee work independently	Transmits attitudes and values of experts in the field	

	Great Extent			Not at all
Overall the SRP influenced me :	4	3	2	1

Part IV. Course taking and career decisions

Please state the name of your university, and list your majors: ______________________

____

If you were in a science course, please answer the following section, beginning with **Question 44** and indicate the extent to which you agree with the following statements.

If you were **not** enrolled in a science course, please proceed to **Question 52.**

	SA	A	D	SD
44. I enjoyed my science classes in university				
45. I had a very good mentor who encouraged and supported me				
46. I had been awarded a scholarship to pursue science				
47. I had very good grades for science at the 'A' Level exams				
48. I enjoyed my science classes in junior college				
49. I hoped to make a contribution in the sciences				
50. Other comments:				

	Yes	No
51. I am willing to be a mentor in SRP		

Please proceed to the section on ***career decisions on*** **Page 10.**

For Y1990 cohort only (SC)

Please indicate the degree to which you agree with the following reasons why you opted for a non- science course:

	SA	A	D	SD
52. I could not get the science course of my first choice or at the university of my first choice.				
53. I was more interested in non-science courses.				
54. I had decided to pursue a non science career.				
55. I had been awarded a scholarship to pursue a non-science course.				
56. I did not enjoy my science classes in junior college.				
57. I did not make good grades for the science papers at the 'A' Level exam.				
58. Other comments:				
59. Will you return to science in the future?				

For Y1990 cohort only (NSC)

Career decisions

Please state your current occupation. ____________________________

If it is in the **sciences**, please answer the following section beginning with **<u>Question 60.</u>**

If this is your first job, and it is **not science-related even though you pursued a science course** in university, please proceed to **<u>Question 66.</u>**

If you had a science career before and **have left it**, please proceed to **<u>Question 73.</u>**

If this is your first job, and it is not science-related because you pursued a non-science course, proceed to **<u>Question 83.</u>**

	SA	A	D	SD
60. I had always wanted a career in the sciences.				
61. My current job pays well.				
62. I am doing something that I really enjoy and am passionate about.				
63. I do not think I will do well in a career outside science.				
64. I plan to pursue further studies in science.				

65. Do you have any plans to leave the field and go into a non-science career? Yes/No
If you answered **Yes**, please give your reasons:

Please proceed to **<u>Question 80</u>** on p12.

Y 1990 cohort only (SP)

Reasons for not pursuing a career in science

	SA	A	D	SD
66. I did not enjoy my science course at university.				
67. I knew I did not have the temperament to pursue a career in science.				
68. I was told that most science careers involve long hours of work.				
69. I was discouraged by people who were in science careers and regretted their decision.				
70. I may consider a career in the sciences in the future.				
71. I was disillusioned by what I experienced in university.				
72. Other reasons/comments:				

Please proceed to **Question 80** on p.12.

Y 1990 cohort (NSP)

Please indicate the degree to which you agree with the following reasons for your decision to leave a career in science.

	SA	A	D	SD
73. I did not enjoy my work at all.				
74. The hours were too long.				
75. The pay was too low.				
76. The work place was not very friendly.				
77. I could not stand the politics in the workplace.				
78. I was offered another job which was too good to turn down.				
79. Other reasons/comments:				

80. I plan to work full time even when I have children. Yes [ ] No [ ]

Y1990 cohort (NSP- exit)

Part V. Role of teachers/school

*81. Please indicate in rank order (with **1** being MOST essential and **3** being LEAST essential) the **three** most essential qualities of an effective science teacher:*

	Deep content knowledge	Passion for the subject	
	Curious about the world	Models the habits of mind of a scientist	
	Genuine interest in student as an individual	Prepares students well for national exams	
	Willingness to discuss topic beyond syllabus	Available for consultation after class	
	Very clear in his/her teaching	Prepares lessons well	
	Sense of humor	Open to divergent ideas	
	Asks the right questions	Makes connections to other subjects	
	Discusses applications to real life	Other:	

82. Please name a science teacher you had in secondary school or Junior College who has left a deep impression on you.

Name: ______________________________

Subject & level taught: ___________________

School: _____________________________

Please describe this teacher's qualities and how he/she impacted you.

____
____
____
____
____

83. There are people who believe that children who show exceptional abilities should be allowed to be accelerated and proceed at their own pace, ahead of their age peers. What are your views on this practice?

____
____
____
____

84. Who would you say is the most important person responsible for the development of your science talent?

Self: __________ Father: _________
Teacher: __________ Mother: _________
Mentor: __________ Sibling: _________
Other: ___________

85. Has anyone (father, mother, teacher, sibling, etc.) ever tried to discourage you in the development of your science talent? Yes___ No___ If yes, what was the reason the person gave you?

____
____

Part VI: Personal values and beliefs

86. Please indicate the degree to which you agree with each of the following statements about your personal values and beliefs.

	SA	A	D	SD
I believe it takes a lot of hard work to develop one's gifts.				
I believe hard work is more important for success than talent.				
When I make plans, I make sure they work out.				
I attribute what I have achieved in school so far to my abilities.				
For one to be successful, good luck is more important than hard work.				
I like to set goals for myself. I am internally driven.				
I am a team player and like to work collaboratively with others.				
Most of the time, when I do something, I do it because I enjoy it.				
I am a non-conformist.				
I tend to work hard, and persist at something, even after others have given up.				
I would like to be remembered for my contributions to society.				
I tend to be solitary.				

Part VII. Parental influence on your education and development

Please use the scale below to rate the extent to which you agree with each of the following statements about your parents' influence on your education and development.

1	2	3	4
Always	Usually	Sometimes	Never

87. When I was in secondary school	1	2	3	4
My parents expected me to be among the top three scorers in class.				
My parent(s) would show disappointment when I did not perform up to expectations.				
My parent(s) would check to make sure I did my homework.				
My parent(s) always compared my performance to that of my siblings and/or my parents' friends' children.				
My parent(s) set very high expectations for me.				
My parent(s) would praise me for doing well in school.				
I would be afraid to tell my parent(s) if I did not get a good grade.				
My parent(s) discussed interesting science topics at home.				
My parent(s) would set homework for me to do.				
My parent(s) was/were strict with me.				
My parent(s) exerted pressure on me to do well.				
My parents encouraged me to pursue my interests.				
My parent(s) felt it was their responsibility to help me with schoolwork.				
My parent(s) set the number of hours I should study to prepare for tests and exams.				
My parent(s) would buy books for the home to encourage me to read.				
My parent(s) would take me to the library or museum.				
My parent(s) would explain to me where I had gone wrong when they went through a test or homework with me.				
My parent(s) hired a tutor for me when they felt I needed one.				
My parent(s) would enroll me for enrichment programs during the vacation.				
My parent(s) expected me to go to university.				

Part VIII. Career views

i. Your specific job title: ______________________________

ii. Current employer: ________________________________

iii. No. of years in this position: ___________________________

iv. Annual income (to the closes $10, 000) _________________

v. Average number of hours per (typical) week: _____________

88. Please rate the extent to which you agree with each of the following statements describing your feelings about your work:

	SA	A	D	SD
a. I truly enjoy my work.				
b. I do not mind the long working hours.				
c. Work is my passion.				
d. My work is the most important to me.				
e. I do not have difficulties balancing the demands of work and family.				
f. I enjoy talking about my work.				
g. The work I do has a positive impact on others.				
h. I am very satisfied with my present career.				

i. **For those in a science career:**

Please indicate your role in the sciences by checking (/) all that apply

	I am a researcher	I am in an applied field e.g. medicine	
	I am a technician	I am in a pure science field (e.g. biology)	
	I am a teacher/professor	I hold an administrative post in a science organization e.g. research institute	
	I am a doctor/surgeon	I work in a science facility	
	I am an engineer	I work with others on projects	
		I work alone on studies.	

Please share how your experience in the SRP has influenced (or not influenced) your decision to be in this career, and your attitude towards your scientific work.

____

____

____

____

____

89. There have been many changes in the decade since you first made your course and career decisions. In the light of the advancements in science and technology and their impact on society and humanity, are there markers that you could point to that might have influenced your decisions differently and/or will influence the career decisions you make in the future? Please elaborate.

90. Is there anything that you have not been asked that would help us understand the influences on the talent development process in science that you have experienced and the developmental path you have chosen? Please explain.

- ***The end. Thank you so much for your time and views. -***

Would you like to have a copy of the findings? If yes, please leave an address where we can mail you the report.

Street address: Or Email address:

NUS National University of Singapore FoS Faculty of Science

13 October 2004

Dear graduates of the Science Research Programme (SRP),

Follow-up Study on SRP graduates

This year marks the 17th year of the SRP. As you are aware, the idea for this programme was mooted by Dr Tony Tan when he was Minister for Education. It was launched in 1988 by the Faculty of Science jointly with the Gifted Education Branch, Ministry of Education, for talented Junior College students to have a chance to experience real-world research, principally in science, engineering science and medical science.

To date, the programme has benefited over a thousand participants and it is timely for us to launch a follow-up study. We are interested in studying how the participants are faring in their professional and personal lives, their interests and also the impact of the SRP on their choice of undergraduate/graduate education. All graduates of the SRP have been invited to participate in the follow-up study.

In addition to a survey questionnaire for all SRPians, two other in-depth studies would be conducted on a few selected batches. The first in-depth study is to isolate the factors that influence talent development in the sciences while the second is to investigate the factors that influence talented females' long-term commitment to mathematics, science and engineering pathways.

Your views and candid feedback will provide us with an understanding of better learning journeys in the future for students like yourself who have demonstrated interest in scientific research whilst in school. As greater emphasis in the broader and more flexible junior college and upper secondary curriculum will be given to independent thinking and creative exploration, in-depth research work will be an important component of the admission criteria to a tertiary education in Singapore from 2006 onwards. Your views will be relevant and also benefit future cohorts of SRP participants.

Both the on-line version of the survey questionnaire and the printed form are available on 15 November 2004. Should you have any questions or concerns about the follow-up study, please contact Miss Mary Han at mary_han@moe.gov.sg.

We look forward to your participation in the follow-up study. Thank you.

Assoc Professor Lim Tit Meng
Vice Dean and Chairman of the SRPCC

Range of co-curricular activities of SRP students

Sports/Uniformed Groups	**# of students**
Athletics, air rifle, archery	21
Judo, taekwondo, wushu, fencing	21
Water sports – swimming, dragon boat, canoeing	10
Games e.g. Hockey, squash, badminton	29
Uniformed Groups	16
Clubs/societies	
Math/Science clubs	48[8]
Multimedia/Information Technology	16
Chess/bridge	15
Performing arts – band, orchestra, dance, choral groups	55[9]
Community service/school leader	41

[8] Many students were members of more than one club

[9] Actual number of students in at least ***one*** of the activities was 41. Several of them were active in more than one activity.

Factors contributing to early interest in science: ANOVA by Gender

		Sum of Squares	df	Mean Square	F	Sig.
stimulating lessons in school	Between Groups	.194	1	.194	.468	.495
	Within Groups	63.393	153	.414		
	Total	63.587	154			
encouraging teachers	Between Groups	.009	1	.009	.025	.875
	Within Groups	56.288	153	.368		
	Total	56.297	154			
inspiring role models	Between Groups	.993	1	.993	2.051	.154
	Within Groups	74.078	153	.484		
	Total	75.071	154			
availability of resources in school	Between Groups	.112	1	.112	.225	.636
	Within Groups	76.107	153	.497		
	Total	76.219	154			
enrichment opportunities in school	Between Groups	.028	1	.028	.060	.807
	Within Groups	71.069	153	.465		
	Total	71.097	154			
good grades in science	Between Groups	3.319	1	3.319	6.000	.015
	Within Groups	84.617	153	.553		
	Total	87.935	154			
peers with similar interest	Between Groups	.407	1	.407	.646	.423
	Within Groups	96.432	153	.630		
	Total	96.839	154			
co-curricular activities	Between Groups	.991	1	.991	1.558	.214
	Within Groups	97.293	153	.636		
	Total	98.284	154			
parents work in science field	Between Groups	.501	1	.501	.736	.392
	Within Groups	104.234	153	.681		
	Total	104.735	154			
parental influence	Between Groups	1.340	1	1.340	1.669	.198
	Within Groups	122.828	153	.803		
	Total	124.168	154			
freedom to explore my own interests	Between Groups	1.768	1	1.768	3.948	.049
	Within Groups	68.528	153	.448		
	Total	70.297	154			
presence of non fiction resources at home	Between Groups	2.763	1	2.763	3.948	.049
	Within Groups	106.361	152	.700		
	Total	109.123	153			
leisure time with family	Between Groups	.027	1	.027	.042	.838
	Within Groups	98.592	153	.644		
	Total	98.619	154			
influence of siblings	Between Groups	.405	1	.405	.631	.428
	Within Groups	85.343	133	.642		
	Total	85.748	134			
enrolment in special enrichment programs that emphasized science learning	Between Groups	1.759	1	1.759	2.726	.101
	Within Groups	98.718	153	.645		
	Total	100.477	154			

Factors contributing to early interest in science ANOVA by Cohort

		Sum of Squares	df	Mean Square	F	Sig.
stimulating lessons in school	Between Groups	2.181	2	1.091	2.700	.070
	Within Groups	61.406	152	.404		
	Total	63.587	154			
encouraging teachers	Between Groups	.767	2	.384	1.050	.352
	Within Groups	55.529	152	.365		
	Total	56.297	154			
inspiring role models	Between Groups	.462	2	.231	.470	.626
	Within Groups	74.609	152	.491		
	Total	75.071	154			
availability of resources in school	Between Groups	.349	2	.175	.350	.706
	Within Groups	75.870	152	.499		
	Total	76.219	154			
enrichment opportunities in school	Between Groups	4.284	2	2.142	4.873	.009
	Within Groups	66.812	152	.440		
	Total	71.097	154			
good grades in science	Between Groups	2.461	2	1.230	2.188	.116
	Within Groups	85.475	152	.562		
	Total	87.935	154			
peers with similar interest	Between Groups	2.806	2	1.403	2.268	.107
	Within Groups	94.032	152	.619		
	Total	96.839	154			
co-curricular activities	Between Groups	1.758	2	.879	1.384	.254
	Within Groups	96.526	152	.635		
	Total	98.284	154			
parents work in science field	Between Groups	1.913	2	.957	1.414	.246
	Within Groups	102.822	152	.676		
	Total	104.735	154			
parental influence	Between Groups	.578	2	.289	.355	.701
	Within Groups	123.590	152	.813		
	Total	124.168	154			
freedom to explore my own interests	Between Groups	2.168	2	1.084	2.418	.093
	Within Groups	68.129	152	.448		
	Total	70.297	154			
presence of non fiction resources at home	Between Groups	.705	2	.352	.491	.613
	Within Groups	108.419	151	.718		
	Total	109.123	153			
leisure time with family	Between Groups	1.470	2	.735	1.150	.319
	Within Groups	97.150	152	.639		
	Total	98.619	154			
influence of siblings	Between Groups	1.777	2	.888	1.397	.251
	Within Groups	83.971	132	.636		
	Total	85.748	134			
enrolment in special enrichment programs that emphasized science learning	Between Groups	2.943	2	1.471	2.293	.104
	Within Groups	97.534	152	.642		
	Total	100.477	154			

Reasons for joining SRP ANOVA by Gender

		Sum of Squares	df	Mean Square	F	Sig.
to observe scientists/researchers at work	Between Groups	.806	1	.806	1.594	.209
	Within Groups	77.349	153	.506		
	Total	78.155	154			
to be able to research an area of interest in depth	Between Groups	.223	1	.223	.515	.474
	Within Groups	66.319	153	.433		
	Total	66.542	154			
to find out what scientific research is	Between Groups	1.675	1	1.675	4.558	.034
	Within Groups	56.222	153	.367		
	Total	57.897	154			
to follow up on teachers' encouragement	Between Groups	2.496	1	2.496	4.781	.030
	Within Groups	79.355	152	.522		
	Total	81.851	153			
to satisfy parents' desire to have me participate	Between Groups	3.182	1	3.182	8.881	.003
	Within Groups	54.455	152	.358		
	Total	57.636	153			
to respond to my peer group	Between Groups	.624	1	.624	1.336	.250
	Within Groups	70.986	152	.467		
	Total	71.610	153			
to benefit from the prestige of the program	Between Groups	2.110	1	2.110	3.255	.073
	Within Groups	98.514	152	.648		
	Total	100.623	153			
to improve the chances of getting a scholarship to university	Between Groups	6.624	1	6.624	10.504	.001
	Within Groups	95.850	152	.631		
	Total	102.474	153			
to have access to university labs and state of the art facilities	Between Groups	.401	1	.401	.613	.435
	Within Groups	100.076	153	.654		
	Total	100.477	154			
to respond to a sibling who had been a participant who encouraged me	Between Groups	.016	1	.016	.045	.832
	Within Groups	45.733	133	.344		
	Total	45.748	134			
to see if I have what it takes to be a scientist/researcher	Between Groups	.963	1	.963	2.150	.145
	Within Groups	68.546	153	.448		
	Total	69.510	154			
to get the glimpse of the life of a scientist	Between Groups	1.145	1	1.145	3.219	.075
	Within Groups	54.082	152	.356		
	Total	55.227	153			
to have a mentor to discuss my interests with	Between Groups	.286	1	.286	.540	.464
	Within Groups	80.623	152	.530		
	Total	80.909	153			

Reasons for joining SRP ANOVA by Cohort

		Sum of Squares	df	Mean Square	F	Sig.
to observe scientists/researchers at work	Between Groups	1.280	2	.640	1.265	.285
	Within Groups	76.875	152	.506		
	Total	78.155	154			
to be able to research an area of interest in depth	Between Groups	3.393	2	1.697	4.084	.019
	Within Groups	63.149	152	.415		
	Total	66.542	154			
to find out what scientific research is	Between Groups	.516	2	.258	.684	.506
	Within Groups	57.380	152	.378		
	Total	57.897	154			
to follow up on teachers' encouragement	Between Groups	.506	2	.253	.469	.626
	Within Groups	81.345	151	.539		
	Total	81.851	153			
to satisfy parents' desire to have me participate	Between Groups	.769	2	.384	1.021	.363
	Within Groups	56.868	151	.377		
	Total	57.636	153			
to respond to my peer group	Between Groups	.047	2	.024	.050	.951
	Within Groups	71.563	151	.474		
	Total	71.610	153			
to benefit from the prestige of the program	Between Groups	1.296	2	.648	.985	.376
	Within Groups	99.327	151	.658		
	Total	100.623	153			
to improve the chances of getting a scholarship to university	Between Groups	3.165	2	1.583	2.406	.094
	Within Groups	99.309	151	.658		
	Total	102.474	153			
to have access to university labs and state of the art facilities	Between Groups	.140	2	.070	.106	.900
	Within Groups	100.338	152	.660		
	Total	100.477	154			
to respond to a sibling who had been a participant who encouraged me	Between Groups	.840	2	.420	1.234	.294
	Within Groups	44.908	132	.340		
	Total	45.748	134			
to see if I have what it takes to be a scientist/researcher	Between Groups	.474	2	.237	.522	.595
	Within Groups	69.036	152	.454		
	Total	69.510	154			
to get the glimpse of the life of a scientist	Between Groups	.089	2	.044	.121	.886
	Within Groups	55.139	151	.365		
	Total	55.227	153			
to have a mentor to discuss my interests with	Between Groups	1.808	2	.904	1.726	.182
	Within Groups	79.101	151	.524		
	Total	80.909	153			

Impact of SRP ANOVA by Gender

		Sum of Squares	df	Mean Square	F	Sig.
SRP further stimulated my interest in science	Between Groups	.623	1	.623	1.266	.262
	Within Groups	75.351	153	.492		
	Total	75.974	154			
SRP affirmed my interest in science research	Between Groups	.136	1	.136	.229	.633
	Within Groups	91.051	153	.595		
	Total	91.187	154			
SRP deepened my knowledge beyond what the school curriculum could offer	Between Groups	2.461	1	2.461	5.586	.019
	Within Groups	67.410	153	.441		
	Total	69.871	154			
SRP sharpened my scientific investigative skills	Between Groups	.054	1	.054	.110	.741
	Within Groups	75.855	153	.496		
	Total	75.910	154			
SRP exposed me to different career possibilities in science	Between Groups	2.025	1	2.025	3.574	.061
	Within Groups	86.659	153	.566		
	Total	88.684	154			
SRP strengthened my resolve to pursue science at university	Between Groups	1.342	1	1.342	1.959	.164
	Within Groups	104.826	153	.685		
	Total	106.168	154			
SRP made me surer that I wanted to pursue a career in science	Between Groups	2.682	1	2.682	3.563	.061
	Within Groups	115.189	153	.753		
	Total	117.871	154			

Impact of SRP ANOVA by Cohort

		Sum of Squares	df	Mean Square	F	Sig.
SRP further stimulated my interest in science	Between Groups	1.691	2	.846	1.731	.181
	Within Groups	74.283	152	.489		
	Total	75.974	154			
SRP affirmed my interest in science research	Between Groups	.736	2	.368	.619	.540
	Within Groups	90.451	152	.595		
	Total	91.187	154			
SRP deepened my knowledge beyond what the school curriculum could offer	Between Groups	.304	2	.152	.333	.718
	Within Groups	69.567	152	.458		
	Total	69.871	154			
SRP sharpened my scientific investigative skills	Between Groups	.453	2	.226	.456	.635
	Within Groups	75.457	152	.496		
	Total	75.910	154			
SRP exposed me to different career possibilities in science	Between Groups	.410	2	.205	.353	.703
	Within Groups	88.274	152	.581		
	Total	88.684	154			
SRP strengthened my resolve to pursue science at university	Between Groups	3.525	2	1.762	2.610	.077
	Within Groups	102.643	152	.675		
	Total	106.168	154			
SRP made me surer that I wanted to pursue a career in science	Between Groups	7.119	2	3.560	4.885	.009
	Within Groups	110.752	152	.729		
	Total	117.871	154			

Impact of mentor ANOVA by Gender

		Sum of Squares	df	Mean Square	F	Sig.
taught me skills in scientific research	Between Groups	2.287	2	1.143	2.422	.092
	Within Groups	71.298	151	.472		
	Total	73.584	153			
exemplified the qualities of a scientist	Between Groups	6.324	2	3.162	5.815	.004
	Within Groups	81.571	150	.544		
	Total	87.895	152			
was passionate about his work	Between Groups	5.347	2	2.673	5.913	.003
	Within Groups	68.264	151	.452		
	Total	73.610	153			
cared for me as an individual	Between Groups	2.625	2	1.312	1.881	.156
	Within Groups	105.349	151	.698		
	Total	107.974	153			
was an excellent role model	Between Groups	3.253	2	1.627	2.474	.088
	Within Groups	98.642	150	.658		
	Total	101.895	152			
inspired me to consider a career in science research	Between Groups	3.911	2	1.955	2.780	.065
	Within Groups	106.200	151	.703		
	Total	110.110	153			

Impact of mentor ANOVA by cohort

		Sum of Squares	df	Mean Square	F	Sig.
taught me skills in scientific research	Between Groups	2.287	2	1.143	2.422	.092
	Within Groups	71.298	151	.472		
	Total	73.584	153			
exemplified the qualities of a scientist	Between Groups	6.324	2	3.162	5.815	.004
	Within Groups	81.571	150	.544		
	Total	87.895	152			
was passionate about his work	Between Groups	5.347	2	2.673	5.913	.003
	Within Groups	68.264	151	.452		
	Total	73.610	153			
cared for me as an individual	Between Groups	2.625	2	1.312	1.881	.156
	Within Groups	105.349	151	.698		
	Total	107.974	153			
was an excellent role model	Between Groups	3.253	2	1.627	2.474	.088
	Within Groups	98.642	150	.658		
	Total	101.895	152			
inspired me to consider a career in science research	Between Groups	3.911	2	1.955	2.780	.065
	Within Groups	106.200	151	.703		
	Total	110.110	153			

Post Hoc

exemplified the qualities of a scientist

Tukey HSD

COHORT	N	Subset for alpha = .05	
		1	2
Y2000	52	2.79	
Y1991	28	2.93	2.93
Y2003	73		3.23
Sig.		.649	.134

Means for groups in homogeneous subsets are displayed.
A Uses Harmonic Mean Sample Size = 43.704.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Was passionate about his work

Tukey HSD

COHORT	N	Subset for alpha = .05	
		1	2
Y2000	52	3.02	
Y1991	29	3.24	3.24
Y2003	73		3.44
Sig.		.267	.353

Means for groups in homogeneous subsets are displayed.
A Uses Harmonic Mean Sample Size = 44.502.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Parental influence ANOVA by Gender

		Sum of Squares	df	Mean Square	F	Sig.
my parents expected me to be among the top 3 scorers in class	Between Groups	3.813	1	3.813	4.099	.045
	Within Groups	142.342	153	.930		
	Total	146.155	154			
my parents would show disappointment when I did not perform up to expectations	Between Groups	.814	1	.814	.777	.379
	Within Groups	160.283	153	1.048		
	Total	161.097	154			
my parents would check to make sure I did my homework	Between Groups	.120	1	.120	.145	.704
	Within Groups	126.821	153	.829		
	Total	126.942	154			
my parents always compared my performance to that of my siblings and that of my parents' friends' children	Between Groups	.098	1	.098	.118	.732
	Within Groups	127.025	152	.836		
	Total	127.123	153			
my parents set very high expectations for me	Between Groups	1.060	1	1.060	.919	.339
	Within Groups	176.578	153	1.154		
	Total	177.639	154			
my parents would praise me for doing well in school	Between Groups	1.937	1	1.937	2.309	.131
	Within Groups	128.347	153	.839		
	Total	130.284	154			
I would be afraid to tell my parents if I did not get a good grade	Between Groups	.234	1	.234	.241	.624
	Within Groups	148.759	153	.972		
	Total	148.994	154			
my parents would discuss science topics at dinner time	Between Groups	.773	1	.773	1.281	.259
	Within Groups	92.324	153	.603		
	Total	93.097	154			
my parents would set homework for me to do	Between Groups	.215	1	.215	.438	.509
	Within Groups	74.985	153	.490		
	Total	75.200	154			
my parents were strict with me	Between Groups	.531	1	.531	.620	.432
	Within Groups	130.979	153	.856		
	Total	131.510	154			
my parents exerted pressure on me to do well	Between Groups	.001	1	.001	.001	.977
	Within Groups	124.941	153	.817		
	Total	124.942	154			
my parents encouraged me to pursue my interests	Between Groups	.374	1	.374	.563	.454
	Within Groups	101.600	153	.664		
	Total	101.974	154			

my parents felt it was their responsibility to help me with school work	Between Groups	.225	1	.225	.302	.583
	Within Groups	114.071	153	.746		
	Total	114.297	154			
my parents set the number of hours i should study to prepare for tests and exams	Between Groups	.565	1	.565	2.105	.149
	Within Groups	41.074	153	.268		
	Total	41.639	154			
my parents would buy books for the home to encourage me to read	Between Groups	.586	1	.586	.536	.465
	Within Groups	167.182	153	1.093		
	Total	167.768	154			
my parents would take me to the library or museum	Between Groups	.010	1	.010	.011	.915
	Within Groups	130.468	153	.853		
	Total	130.477	154			
my parents would explain to me where I had gone wrong when they went through a test or homework with me	Between Groups	1.523	1	1.523	2.634	.107
	Within Groups	87.880	152	.578		
	Total	89.403	153			
my parents hired a tutor for me when they felt I needed one	Between Groups	3.174	1	3.174	2.911	.090
	Within Groups	166.826	153	1.090		
	Total	170.000	154			
my parents would enroll me for enrichment programs during the vacation	Between Groups	1.559	1	1.559	3.162	.077
	Within Groups	74.941	152	.493		
	Total	76.500	153			
my parents expected me to go to university	Between Groups	.943	1	.943	1.663	.199
	Within Groups	86.799	153	.567		
	Total	87.742	154			

Parental influence ANOVA by cohort

		Sum of Squares	df	Mean Square	F	Sig.
my parents expected me to be among the top 3 scorers in class	Between Groups	.658	2	.329	.343	.710
	Within Groups	145.497	152	.957		
	Total	146.155	154			
my parents would show disappointment when i did not perform up to expectations	Between Groups	.466	2	.233	.220	.802
	Within Groups	160.631	152	1.057		
	Total	161.097	154			
my parents would check to make sure I did my homework	Between Groups	.809	2	.405	.487	.615
	Within Groups	126.133	152	.830		
	Total	126.942	154			
my parents always compared my performance to that of my siblings and that of my parents' friends' children	Between Groups	.755	2	.378	.451	.638
	Within Groups	126.368	151	.837		
	Total	127.123	153			
my parents set very high expectations for me	Between Groups	.029	2	.014	.012	.988
	Within Groups	177.610	152	1.168		
	Total	177.639	154			
my parents would praise me for doing well in school	Between Groups	.110	2	.055	.064	.938
	Within Groups	130.174	152	.856		
	Total	130.284	154			
I would be afraid to tell my parents if I did not get a good grade	Between Groups	3.822	2	1.911	2.001	.139
	Within Groups	145.171	152	.955		
	Total	148.994	154			
my parents would discuss science topics at dinner time	Between Groups	.318	2	.159	.261	.771
	Within Groups	92.778	152	.610		
	Total	93.097	154			
my parents would set homework for me to do	Between Groups	2.886	2	1.443	3.033	.051
	Within Groups	72.314	152	.476		
	Total	75.200	154			
my parents were strict with me	Between Groups	1.747	2	.874	1.023	.362
	Within Groups	129.762	152	.854		
	Total	131.510	154			
my parents exerted pressure on me to do well	Between Groups	.397	2	.198	.242	.785
	Within Groups	124.545	152	.819		
	Total	124.942	154			
my parents encouraged me to pursue my interests	Between Groups	.250	2	.125	.187	.830
	Within Groups	101.724	152	.669		
	Total	101.974	154			

my parents felt it was their responsibility to help me with school work	Between Groups	.504	2	.252	.337	.715
	Within Groups	113.792	152	.749		
	Total	114.297	154			
my parents set the number of hours I should study to prepare for tests and exams	Between Groups	1.346	2	.673	2.539	.082
	Within Groups	40.292	152	.265		
	Total	41.639	154			
my parents would buy books for the home to encourage me to read	Between Groups	8.265	2	4.132	3.938	.022
	Within Groups	159.503	152	1.049		
	Total	167.768	154			
my parents would take me to the library or museum	Between Groups	2.901	2	1.451	1.728	.181
	Within Groups	127.576	152	.839		
	Total	130.477	154			
my parents would explain to me where I had gone wrong when they went through a test or homework with me	Between Groups	5.066	2	2.533	4.535	.012
	Within Groups	84.337	151	.559		
	Total	89.403	153			
my parents hired a tutor for me when they felt i needed one	Between Groups	3.448	2	1.724	1.573	.211
	Within Groups	166.552	152	1.096		
	Total	170.000	154			
my parents would enroll me for enrichment programs during the vacation	Between Groups	.425	2	.212	.422	.657
	Within Groups	76.075	151	.504		
	Total	76.500	153			
my parents expected me to go to university	Between Groups	.188	2	.094	.163	.850
	Within Groups	87.554	152	.576		
	Total	87.742	154			

my parents would set homework for me to do
Tukey HSD

COHORT	N	Subset for alpha = .05	
		1	2
Y1991	30	3.37	
Y2000	52	3.56	3.56
Y2003	73		3.73
Sig.		.388	.478

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 45.274.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

my parents would buy books for the home to encourage me to read
Tukey HSD

COHORT	N	Subset for alpha = .05	
		1	2
Y1991	30	2.50	
Y2003	73		3.03
Y2000	52		3.13
Sig.		1.000	.872

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 45.274.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

ANOVA by Father's Educational Level

		Sum of Squares	df	Mean Square	F	Sig.
my parents expected me to be among the top 3 scorers in class	Between Groups	9.660	1	9.660	10.766	.001
	Within Groups	133.691	149	.897		
	Total	143.351	150			
my parents would show disappointment when I did not perform up to expectations	Between Groups	3.046	1	3.046	2.971	.087
	Within Groups	152.742	149	1.025		
	Total	155.788	150			
my parents would check to make sure I did my homework	Between Groups	1.816	1	1.816	2.211	.139
	Within Groups	122.370	149	.821		
	Total	124.185	150			
my parents always compared my performance to that of my siblings and that of my parents' friends' children	Between Groups	1.121	1	1.121	1.326	.251
	Within Groups	125.172	148	.846		
	Total	126.293	149			
my parents set very high expectations for me	Between Groups	11.818	1	11.818	10.763	.001
	Within Groups	163.599	149	1.098		
	Total	175.417	150			
my parents would praise me for doing well in school	Between Groups	6.775	1	6.775	8.407	.004
	Within Groups	120.086	149	.806		
	Total	126.861	150			
I would be afraid to tell my parents if I did not get a good grade	Between Groups	3.173	1	3.173	3.383	.068
	Within Groups	139.767	149	.938		
	Total	142.940	150			
my parents would discuss science topics at dinner time	Between Groups	6.190	1	6.190	10.959	.001
	Within Groups	84.155	149	.565		
	Total	90.344	150			
my parents would set homework for me to do	Between Groups	.815	1	.815	1.647	.201
	Within Groups	73.728	149	.495		
	Total	74.543	150			
my parents were strict with me	Between Groups	.014	1	.014	.016	.899
	Within Groups	126.728	149	.851		
	Total	126.742	150			
my parents exerted pressure on me to do well	Between Groups	2.243	1	2.243	2.771	.098
	Within Groups	120.592	149	.809		
	Total	122.834	150			
my parents encouraged me to pursue my interests	Between Groups	.054	1	.054	.082	.775
	Within Groups	98.939	149	.664		
	Total	98.993	150			

my parents felt it was their responsibility to help me with school work	Between Groups	4.037	1	4.037	5.562	.020
	Within Groups	108.149	149	.726		
	Total	112.185	150			
my parents set the number of hours I should study to prepare for tests and exams	Between Groups	.391	1	.391	1.421	.235
	Within Groups	41.026	149	.275		
	Total	41.417	150			
my parents would buy books for the home to encourage me to read	Between Groups	12.129	1	12.129	11.992	.001
	Within Groups	150.706	149	1.011		
	Total	162.834	150			
my parents would take me to the library or museum	Between Groups	2.996	1	2.996	3.759	.054
	Within Groups	118.765	149	.797		
	Total	121.762	150			
my parents would explain to me where I had gone wrong when they went through a test or homework with me	Between Groups	4.809	1	4.809	8.536	.004
	Within Groups	83.384	148	.563		
	Total	88.193	149			
my parents hired a tutor for me when they felt I needed one	Between Groups	2.966	1	2.966	2.761	.099
	Within Groups	160.028	149	1.074		
	Total	162.993	150			
my parents would enroll me for enrichment programs during the vacation	Between Groups	1.390	1	1.390	3.021	.084
	Within Groups	68.103	148	.460		
	Total	69.493	149			
my parents expected me to go to university	Between Groups	5.019	1	5.019	9.902	.002
	Within Groups	75.524	149	.507		
	Total	80.543	150			

ANOVA by Mother's Educational Level

		Sum of Squares	df	Mean Square	F	Sig.
my parents expected me to be among the top 3 scorers in class	Between Groups	6.105	1	6.105	6.628	.011
	Within Groups	137.246	149	.921		
	Total	143.351	150			
my parents would show disappointment when I did not perform up to expectations	Between Groups	4.778	1	4.778	4.715	.031
	Within Groups	151.010	149	1.013		
	Total	155.788	150			
my parents would check to make sure I did my homework	Between Groups	.533	1	.533	.642	.424
	Within Groups	123.652	149	.830		
	Total	124.185	150			
my parents always compared my performance to that of my siblings and that of my parents' friends' children	Between Groups	1.076	1	1.076	1.272	.261
	Within Groups	125.217	148	.846		
	Total	126.293	149			
my parents set very high expectations for me	Between Groups	9.973	1	9.973	8.981	.003
	Within Groups	165.445	149	1.110		
	Total	175.417	150			
my parents would praise me for doing well in school	Between Groups	6.917	1	6.917	8.592	.004
	Within Groups	119.944	149	.805		
	Total	126.861	150			
I would be afraid to tell my parents if I did not get a good grade	Between Groups	2.340	1	2.340	2.480	.117
	Within Groups	140.600	149	.944		
	Total	142.940	150			
my parents would discuss science topics at dinner time	Between Groups	8.311	1	8.311	15.096	.000
	Within Groups	82.033	149	.551		
	Total	90.344	150			
my parents would set homework for me to do	Between Groups	.396	1	.396	.797	.374
	Within Groups	74.147	149	.498		
	Total	74.543	150			
my parents were strict with me	Between Groups	.392	1	.392	.463	.497
	Within Groups	126.349	149	.848		
	Total	126.742	150			
my parents exerted pressure on me to do well	Between Groups	1.381	1	1.381	1.695	.195
	Within Groups	121.453	149	.815		
	Total	122.834	150			
my parents encouraged me to pursue my interests	Between Groups	.004	1	.004	.006	.936
	Within Groups	98.989	149	.664		
	Total	98.993	150			

my parents felt it was their responsibility to help me with school work	Between Groups	1.952	1	1.952	2.639	.106
	Within Groups	110.233	149	.740		
	Total	112.185	150			
my parents set the number of hours I should study to prepare for tests and exams	Between Groups	.430	1	.430	1.565	.213
	Within Groups	40.987	149	.275		
	Total	41.417	150			
my parents would buy books for the home to encourage me to read	Between Groups	6.298	1	6.298	5.995	.016
	Within Groups	156.536	149	1.051		
	Total	162.834	150			
my parents would take me to the library or museum	Between Groups	.603	1	.603	.742	.391
	Within Groups	121.159	149	.813		
	Total	121.762	150			
my parents would explain to me where I had gone wrong when they went through a test or homework with me	Between Groups	4.019	1	4.019	7.066	.009
	Within Groups	84.175	148	.569		
	Total	88.193	149			
my parents hired a tutor for me when they felt I needed one	Between Groups	3.749	1	3.749	3.508	.063
	Within Groups	159.244	149	1.069		
	Total	162.993	150			
my parents would enroll me for enrichment programs during the vacation	Between Groups	2.210	1	2.210	4.860	.029
	Within Groups	67.284	148	.455		
	Total	69.493	149			
my parents expected me to go to university	Between Groups	3.505	1	3.505	6.780	.010
	Within Groups	77.038	149	.517		
	Total	80.543	150			

Vita

Chwee Geok Quek

Birthdate : May 19, 1959

Birthplace: Singapore

Education:

2002-2005	The College of William and Mary Williamsburg, Virginia Ph.D. in Educational Policy, Planning and Leadership
1993-1994	The College of William and Mary Williamsburg, Virginia Master of Arts in Education
1982-1983	University of London Institute of Education London, United Kingdom Post Graduate Certificate in Education
1978-1982	The National University of Singapore Singapore Bachelor of Arts